APPENDICES

APPENDIX A

THE INFORMATION OF STUDY FOR

NAM MONG MICRO-HYDROPOWER PLANT

A.1 Introduction

Nam Mong micro-hydropower plant (70kW) was held in 2000 by New Energy Foundation (NEF), Japan and Ministry of Energy and Mining of Lao PDR. It is located Nam Mong village Nam Bak District in Luang Prabang province of Lao PDR.

A.2 The general Information of the Project

A.2.1 Project Location

Nam Mong micro-hydropower plant (MHP) is located the middle of Nam Mong river in the Northern part in Luang Prabang province. From Luang Prabang, Route No. 13 and No.1 are available for reach to the site is about 2 hours by car. Nam Mong river is a relatively small river that is more of the tributaries of Nam Khan river. The total river length is about 40 km and the catchments area is 114 km^2. The location map of the project is shown in table A.1 and figure A.1

Table A.1 The Project Location.

Province	Luang Prabang,
District	Nam Bak,
Village	Nam Mong,
Distance	About 120 km from Luang Prabang, 2 hours by car.

Figure A.1 The Location of Nam Mong MHP.

Since the commissioning ceremony was held on 9 March 2000. The generation of the Nam Mong MHP is continuously generating to 7 villages.

To manage the Nam Mong MHP the Japanese side and the Laos side, were focused to manage and maintenance the project from the construction through the four years of testing. The operation and Maintenance (O&M) organization chart is shown in the figure A.2.

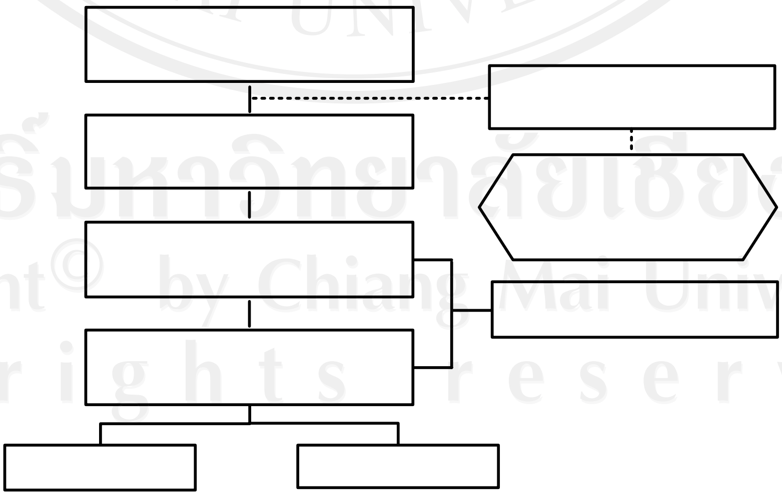


Figure A.2 The Organization Chart of Nam Mong MHP.

A.2.2 Features of Nam Mong Micro-Hydropower plant

1) Features of Generation Plan

Table A.2 Parameters of Generation plan of Nam Mong MHP.

Item	Parameters	Remark
Catchments Area	114 km^2	
Maximum Discharge	0.55 m^3/s	
Intake water level	EL 444.7 m	
Tailrace Water Level	EL 423.9 m	Water level of Tailrace bay
Gross Head	20.80 m	
Loss Head	2.70 m	
Effective Head	18.1 m	
Installed Capacity	70 kW	

Source: [16].

2) Features of Generation Plan

Table A.3 Electro-Mechanical Facilities.

Items	Parameters	
Turbine	Type	Horizontal Shaft Pump Reverse Running Type Generator
	Rating Output	70 kW
	Effective Head	18.1 m
	Maximum Discharge	0.55 m^3/s
	Revolutions	1,000 rpm
	Governor	Dummy Load Type, submergible, 90 kW, AC 400/230V.
Inlet	Range Frequency	47~53 Hz
	Type	Butterfly Valve, manual operated.

Table A.3 (Continued)

Generator	Inner Diameter	450 mm
	Type	Horizontal Shaft, Three Phases, Brushless, Alternating Synchronous Generator
	Rated Capacity	100 kVA (80 kW), (s.f :1.0), 145A
	Frequency	50 Hz,
	Rate Speed	1,000 rpm,
	Over Speed	$\pm$ 200 % of Rate Speed
	Voltage	400 V
	Power Factor	0.8
Step-up Transformer		0.4/22 kV, 100 kVA, Outdoor Type
Lightning Protection		28 kV, 10 kA

Source: [16].

3) Transmission Line and Distribution Line Facilities

The route of transmission line was basically arrangement along and beside by Nam Mong river side of route No. 1 to Oudomxay province. The total of transmission line is 10 km. The distribution line was installed at around 7 villages. The details is shown in table A.4.

Table A.4 Transmission and Distribution Line.

Item	22 kV Transmission Line	0.4 kV Distribution Line
Voltage	22 kV	0.4 kV
Total of Length	10 km	6,85 km

Source:[16].

4) Electrification Progress

Since commissioning in the year 2000, electrification has been progressing satisfactorily and only 65% of household was electrified. In March 2007, Pak Mong village which is once of 7 villages has been disconnected to the Nam Mong's grid and only. The electrification progress is shown in table A.5 and figure A.4 respectively.

Table A.5 Households Electrification Progress of Nam Mong MHP.

No.	Name of Villages	Preminary Sutdy (May.1998)		Villages Households (Mar/2007)	Households Electrification								
		Households	Population		Mar.2000	Jan.2001	Jan.2002	Jan. 2003	Jan.2004	Jan.2005	Jan.2006	Jan.2007	Jan 2008
1)	Nam Mong	45	287	65	-	22	26	30	56	34	39	39	48
2)	Houay Ang	30	173	37	-	15	15	17	19	21	23	23	25
3)	Vang Hinh	56	317	62	-	32	35	38	42	47	52	52	60
4)	Mok Vek	85	516	107	-	52	56	57	61	64	64	64	81
5)	Phonhome	110	748	117	-	61	66	74	79	83	88	88	96
6)	Pak Mong	75	520	114	-	81	85	96	100	100	110	110	0
7)	Vang Kham	68	430	88	-	42	45	46	47	50	51	51	64
	Total	469	2,991	590	120	305	328	358	404	399	427	427	374
The Number of HHWE compared with the villages households by the year 1998 (%)					25.59	65.03	69.94	76.33	86.14	85.07	91.04	91.04	79.74

Note : HHWE : Household with Electrification [16].

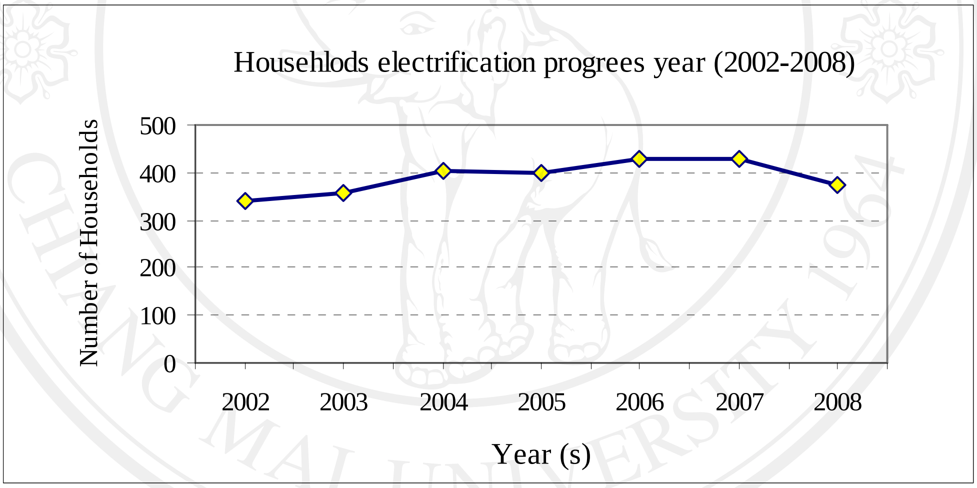


Figure A.3 The households electrification progress of Nam Mong MHP [16].

A.4 Sensitivity Analysis of the Project

The sensitivity NPV, B/C and IRR to several adverse movements in key assumptions has been computed to access the strong effect of the economic analysis of the project. To Evaluate the sensitivity of NPV, B/C and IRR based on discount rate (*r*) of 10%, project cost of 9,900 US$ by varying the following parameters :

1) The sensitivity analysis of NPV, B/C and IRR to discount rate variation
   a) The discount rate is the parameter of interest,
   b) Selected 8% 10% 12% and 15% increment
2) The sensitivity NPV, B/C and IRR to project cost variation
   a) The project cost is the parameter of interest,

b) Selected 10% increment to evaluate sensitivity to the range of the project cost is 10% to 40%,

The economic cash flow of the project was as the base case where the energy of 64,086 kWh/year, electricity tariff of 0.0563 US$/kWh and discount rate of 10%. It was shown in the table A.6.

Table A.6 The Economic Cash flow of the project.

Year	Cost		Benefit			Net Cash Flow (US$)	Discount factor at discount rate 10%	NVP of Net cash Flow (US$)
	Investment cost (US$)	Yearly inspection (US$)	Energy (kWh)	Electricity tariff (US$/kWh)	Amount (US$)			
0	(9,900)					(9,900)		(9,900)
1		(250)	64,086	0.0563	3,608	3,358	0.909	3053
2		(261)	64,086	0.0563	3,608	3,347	0.826	2766
3		(273)	64,086	0.0563	3,608	3,335	0.751	2506
4		(285)	64,086	0.0563	3,608	3,323	0.683	2269
5		(298)	64,086	0.0563	3,608	3,310	0.621	2055
6		(312)	64,086	0.0563	3,608	3,296	0.564	1861
7		(326)	64,086	0.0563	3,608	3,282	0.513	1684
8		(340)	64,086	0.0563	3,608	3,268	0.467	1524
9		(356)	64,086	0.0563	3,608	3,253	0.424	1379
10		(372)	64,086	0.0563	3,608	3,237	0.386	1248
11		(388)	64,086	0.0563	3,608	3,220	0.350	1129
12		(406)	64,086	0.0563	3,608	3,202	0.319	1020
13		(424)	64,086	0.0563	3,608	3,184	0.290	922
14		(443)	64,086	0.0563	3,608	3,165	0.263	833
15		(463)	64,086	0.0563	3,608	3,145	0.239	753
16		(484)	64,086	0.0563	3,608	3,124	0.218	680
17		(506)	64,086	0.0563	3,608	3,102	0.198	614
18		(528)	64,086	0.0563	3,608	3,080	0.180	554
19		(552)	64,086	0.0563	3,608	3,056	0.164	500
20		(577)	64,086	0.0563	3,608	3,031	0.149	451
							Total	**17,901**

Table A.6 (Continued)

Results : Incase of a variation Plant Factor at discount rate of 10%.					
Plant Factor (%)	Base	40%	50%	60%	70%
Energy recovery capacity	**64,086**	123,660	184,980	264,300	307,620
1) NPV of Net Cash Flow (US$)	**17,901**	46,456	75,847	105,239	134,758
2) Internal Rate of Return (IRR)	**33%**	68%	103%	137%	172%
3) Benefit-Cost Ratio (B/C)	**2.40**	4.62	6.92	9.21	11.51
4) Payback Period	**3.69**	1.69	1.08	0.8	0.64
5) Unit Energy Cost (US$/kWh)	**0.0235**	0.0122	0.0081	0.0061	0.0049

Results : Incase of a variation discount rate.				
Discount Rate	8%	**10%**	12%	15%
1) NPV of Net Cash Flow (US$)	22,077	**17,901**	14,550	10,654
2) Internal Rate of Return (IRR) (%)	33%	**33%**	33%	33%
3) Benefit-Cost Ratio (B/C)	2.65	**2.40**	2.17	1.89
4) Payback Period	3.52	**3.69**	3.88	4.22
5) Unit Energy Cost (US$/kWh)	0.0212	**0.0235**	0.0259	0.0297

Results: Incase of increment the project costs.						
Percentage of increment (%)	Base	10%	20%	30%	40%	50%
Cost of increment (US$)	**9,900**	10,890	11,880	12,870	13,860	14,850
1) NPV of Net Cash Flow (US$)	**17,901**	16,911	15,921	14,931	13,941	12,951
2) Internal Rate of Return (IRR)	**33%**	30%	28%	25%	23%	22%
3) Benefit-Cost Ratio (B/C)	**2.40**	2.22	2.08	1.95	1.83	1.73
4) Payback Period (years)	**3.69**	4.82	5.48	6.21	7.01	7.94
5) Unit Energy Cost (US$/kWh)	**0.0235**	0.0253	0.0271	0.0289	0.0307	0.0326

The Benefit-Cost ratio of the project at the project cost was 9,900 US$, the potential energy recovery was 64,086 kWh/year and discount rate was 10%. It was expressed by the following:

1)	Project Life (years)	20
2)	Capital Recovery Factor	0.1175
3)	Initial Investment cost (US$)	9,900
4)	Annual worth of investment Cost (US$/year)	1,163
5)	Annual maintenance cost in Annual worth (US$/year)	343
6)	Annual worth of benefit (US$/year)	3,608
7)	Disbenefit	0

$$B/C = \frac{Benefit \ - \ Disbenefit}{Costs}$$

$$B/C = \frac{3{,}608 \ - \ 0}{1{,}163 \ + \ 343}$$

Therefore, *B/C = 2.397*

The Unit Energy Cost is an important for economic viability of the project. This indicator will provide a guide for determining selling price of energy. Follwing the equation 2.18 in Chapter 2, Section 2.6.2, and the project cost of 9,900 US$, the energy recovery of 64,086 kWh/year and discount rate of 10%the Unit Energy Cost is calculated by the following equation :

1) Capital recovery factor (C*f*) : 0.1175
2) Annualized of Project Cost (US$/year) : (9,900 x 0.1175 = 1,163)
3) Annual running cost (US$/year) : 343
4) *E*: Annual energy Output (kWh/year) : 64,086

$$Unit \ Energy \ Cost = \frac{(Ca + Cr)}{E} = \frac{(1{,}163 + 343)}{64{,}086} = 0.0235 \, US\$ / kWh$$

Therefore, the investment cost of the project per kilowatt hours is Unit Energy Cost that equals to 0.0235 US$/kWh.

To find the discount payback period of the project at a stated discount rate (DR) was 10% calculate the years (n_p) and the project cost was 9,900 US$, the potential energy recovery was 64,086 kWh/year that would be made the following expression:

From equation 2.17, Chapter 2 : $$0 = -P + \sum_{t=1}^{t=n_p} NCF_t \left(P/F, r, t\right)$$

1) Initial Investment cost is 9,900 US$,

From the table A.6 the summation of the NPV of Net cash flow during the year 3th and 4th. They are expressed by the following :

$$\sum_{t=1}^{t=3} NCF_t \left(P/F, 10\%, t\right) = 8{,}324\, US\$ < 9{,}900\, US\$$$

$$\sum_{t=1}^{t=4} NCF_t \left(P/F, 10\%, t\right) = 10{,}594\, US\$ > 9{,}900\, US\$$$

The payback period was available 3 to 4 th-year; the number of year required to recover the investment. It could be defined by the interpolation method.

$$\frac{9{,}900 - 8{,}324}{10{,}594 - 8{,}324} = \frac{n - 3}{4 - 3}$$

$$n = 3.69$$

Therefore, pay back period of the project was 3.69 year(s).

A.3 Study Energy Recovery Potential

From the data record of Nam Mong MHP can make the energy balance with the causes those effects to the plant low of energy generation by comparison at the maximum energy production potential

. They are shown in the table A.6

Where, the maximum energy generation:

70 kW x 24 hours x 365 days = 613,200 kWh/year.

Table A.7 The pattern of energy generation of Nam Mong MHP.

N.o	Item	Unit	Month												Total	
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(kWh)	(%)*
I.	Operating hour(s)	day (s)	31	28	31	30	31	30	31	31	30	31	30	31		
		hour (s)	739	669	718	660	729	716	740	744	697	736	717	730		
II. Power Capacity																
1)	Generating Capacity	kW	19	25	22	24	21	21	20	21	23	21	22	21		
2)	Demand Capacity	kW	13	15	14	16	13	14	13	14	15	14	14	14		
3)	Loss Capacity	kW	5	10	8	8	8	7	6	7	8	7	8	7		
II. Energy Prouction																
1)	Generation	kWh	13,868	16,644	16,018	15,892	15,318	14,923	14,439	15,653	16,148	15,463	16,105	15,082	185,553	30.26%
2)	Consumption	kWh	9,941	10,193	9,934	10,297	9,800	10,023	9,852	10,135	10,792	10,115	10,104	10,167	121,353	19.79%
3)	Surplus	kWh	3,927	6,451	6,084	5,595	5,518	4,901	4,587	5,518	5,355	5,348	6,001	4,915	64,200	10.47%
III. Energy Loss																
1)	Enegy loss recovery potential	kW	51	45	48	46	49	49	50	49	47	49	48	49		
		kWh	37,862	30,186	34,242	30,308	35,712	35,197	37,361	36,427	32,642	36,057	34,085	36,018	416,097	67.86%
2)	Water supply Trouble	hour (s)			23	45	15				20	6			109	
		kWh	0	0	1,610	3,150	1,050	0	0	0	1,400	420	0	0	7,630	1.24%
3)	Maintenance	hour (s)	5			10								10	25	
		kWh	350	0	0	700	0	0	0	0	0	0	0	700	1,750	0.29%
4)	Others	hour (s)		3	3	5		4	4	4	3	2	3		31	
		kWh	0	210	210	350	0	280	280	280	210	140	210	0	2,170	0.35%

Source: The data record of Nam Mong MHP by the year (2006-2007).

Note *The percentage compared the maximum energy generation.

From the table A.7 shows the main cause that effects to the low plant factor is due to the demand lees than supply and they are summarized in table A.8.

Table A.8 The summary of Cause-Effect of generating capacity.

No.	Cause-Effects	Symbol	Energy Capacity	
			(kWh)	(%)
1)	Reality annual energy generating	A	185,553	30.26%
2)	Energy loss due to generating in the condition of demand less than supply	B	416,093	67.86%
3)	Maintenance	C	1,750	0.29%
4)	Water Supply Trouble	D	7,630	1.24%
5)	Others	E	2,170	0.35%
	Total		613,196	100%

Source: Nam Mong MHP energy record year (2006 and 2007)

As seen in table A.8, it was found that, the potential loss was 67.86 % or 416,093 kWh/year can recovery. It was a loss due to the low generated capacity in the condition of demand less than supply and the minor loss extraction due to maintenance shut down water supply trouble and others activities are excluded for further calculation the energy recovery.

From the recommendation of the hydropower plant theory, the small and micro-hydropower plant that is a Run-of-River type it could entirely the maximum generated capacity at plant factor of 70% (See chapter 2, table 2.5).

1) The potential annual energy generation is shown in table A.8

(416,093 kWh/year + 185,553 kWh/year) = 601,606 kWh/year.

2) The annual energy generation at plant factor 70% was

70 kW x 24 hours x 365 days x 70 % = 429,240 kWh/year.

As a result, the potential of energy generation of 601,606 kWh/year was greater than the energy generation of 429,240 kWh/year at plant factor 70%. Therefore, the practical of this study the potential energy recovery of 429,240 kWh/year was available energy for evaluation the economic viability of the project.

The potential of energy recovery of 307,887 kWh/year was from the energy production potential of 429,240 kWh/year minus the energy demand of 121,353 kWh/year. The economic cash flow for the potential of net energy generation at discount rate of 10%, the project cost of 9,900 US$, electricity tariff of 0.0563 US$/kWh was shown in the table A.9

Table A.9 The economic cash flow of Nam Mong MHP project with the energy recovery potential of 307,887 kWh/year.

Year	Cost		Benefit			Net Cash Flow (US$)	Discount factor at discount rate 10%	NPV of Net Cash Flow (US$)
	Investment cost (US$)	Yearly inspection (US$)	Energy (kWh)	Electricity tariff (US$/kWh)	Amount (US$)			
0	(9,900)					(9,900)		(9,900)
1		(250)	307,887	0.0563	17,334	17,084	0.909	15,531
2		(261)	307,887	0.0563	17,334	17,073	0.826	14,110
3		(273)	307,887	0.0563	17,334	17,061	0.751	12,818
4		(285)	307,887	0.0563	17,334	17,049	0.683	11,645
5		(298)	307,887	0.0563	17,334	17,036	0.621	10,578
6		(312)	307,887	0.0563	17,334	17,022	0.564	9,609
7		(326)	307,887	0.0563	17,334	17,008	0.513	8,728
8		(340)	307,887	0.0563	17,334	16,994	0.467	7,928
9		(356)	307,887	0.0563	17,334	16,979	0.424	7,201
10		(372)	307,887	0.0563	17,334	16,963	0.386	6,540
11		(388)	307,887	0.0563	17,334	16,946	0.350	5,939
12		(406)	307,887	0.0563	17,334	16,928	0.319	5,394
13		(424)	307,887	0.0563	17,334	16,910	0.290	4,898
14		(443)	307,887	0.0563	17,334	16,891	0.263	4,448
15		(463)	307,887	0.0563	17,334	16,871	0.239	4,039
16		(484)	307,887	0.0563	17,334	16,850	0.218	3,667
17		(506)	307,887	0.0563	17,334	16,828	0.198	3,329
18		(528)	307,887	0.0563	17,334	16,806	0.180	3,023
19		(552)	307,887	0.0563	17,334	16,782	0.164	2,744
20		(577)	307,887	0.0563	17,334	16,757	0.149	2,491
						Total		134,758

Results:

Discount Rate	10	%	Plant factor:	70	%
Electricity tariff	0.0563	US$/kWh	NPV :	134,758	US$
Energy	307,887	kWh/year	IRR :	172	%
	17,334	US$/year	B/C Ratio :	11.51	
Initial Investment	9,900	US$	Payback Period :	0.64	Year(s)
			Unit Energy Cost :	0.0049	US$/kWh

TYPICAL SINGLE LINE DIAGRAM OF MICRO HYDROPOWER PLANT WITHOUT GRID AND WITH GRID CONNECTION

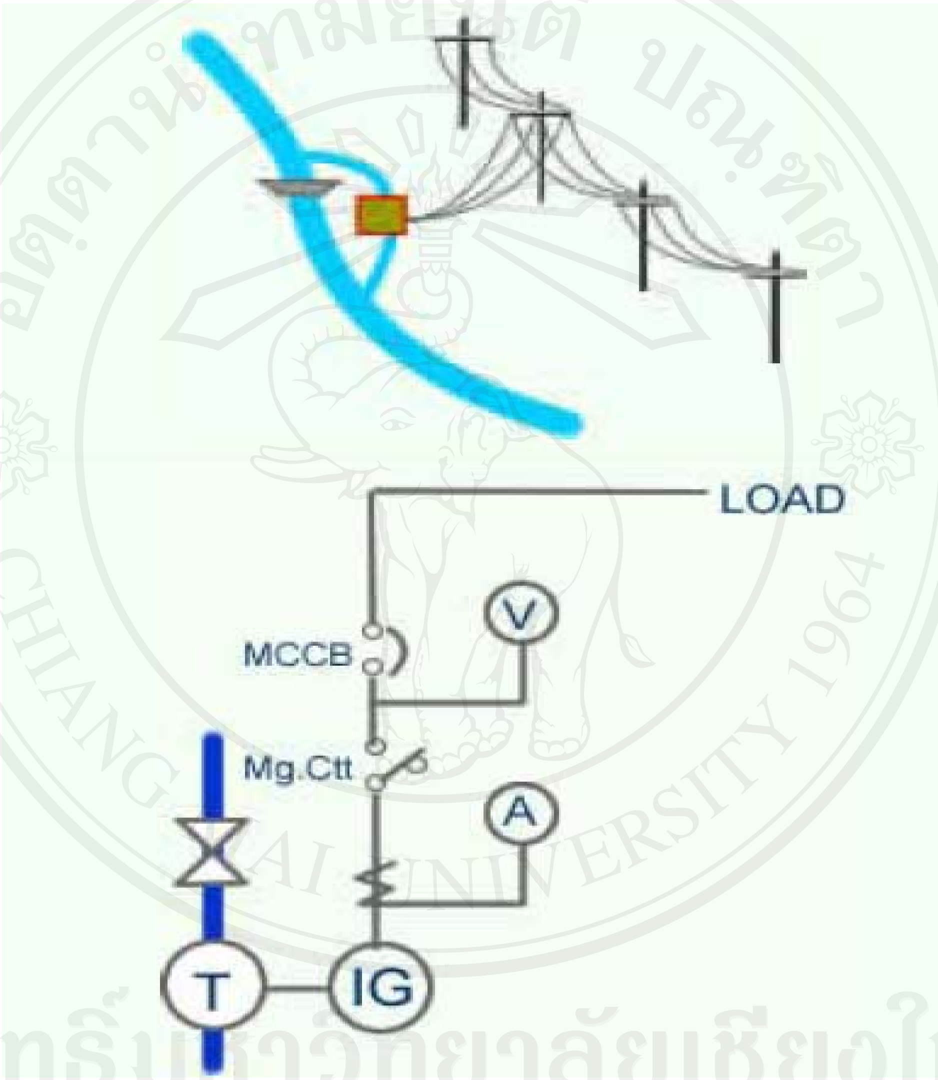


Figure A .4 Single Line Diagram Connecting to the grid [8].

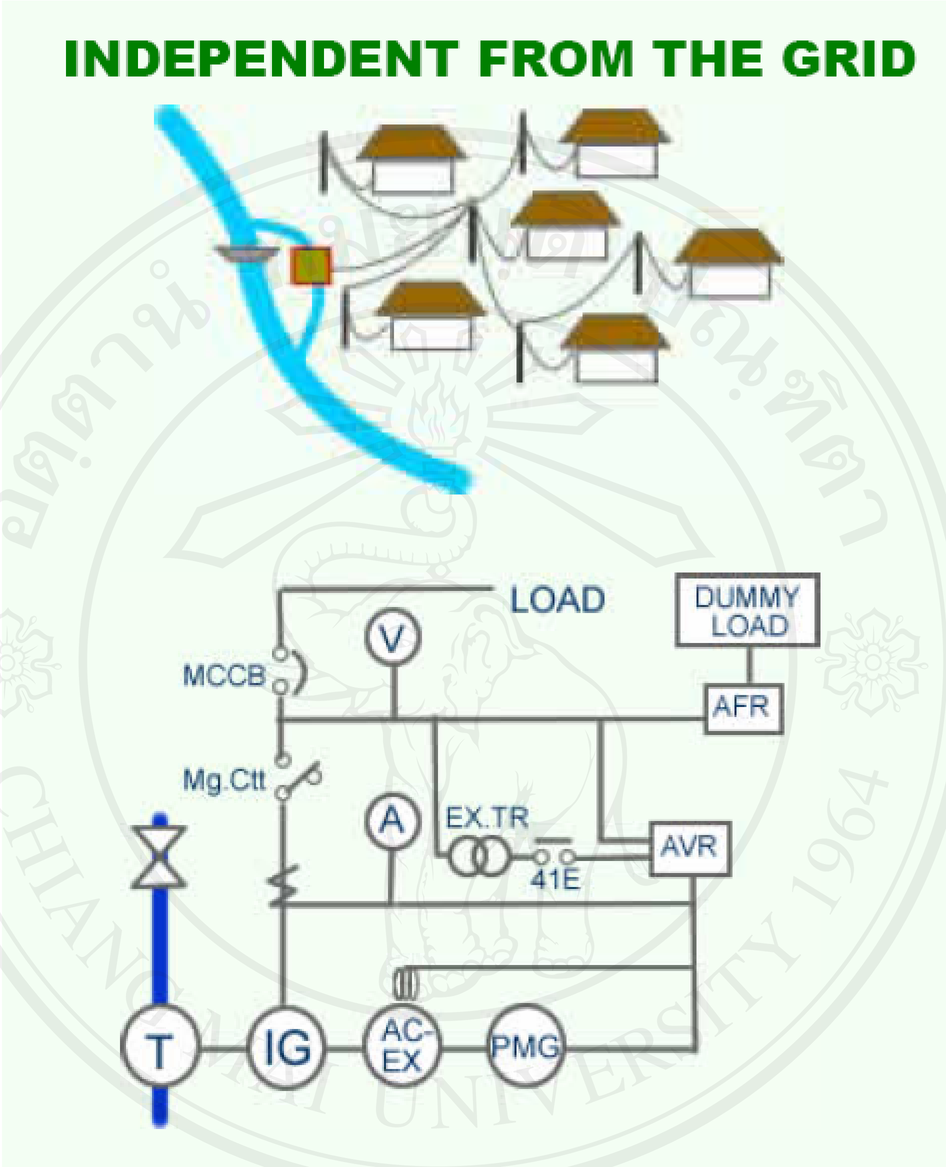


Figure A.5 Single Line Diagram Independent from the grid [8].

Remark :

T : Turbine

IG : Induction Generator

SG : Synchronous Generator

AC. Ex : AC Exciter

PMG : Permanent Magnetic Generator

MCC : Molded Circuit Breaker

AVR : Automatic Voltage Regulator

AFR : Automatic Frequency Regulator

EX.TR : Exciter transformer

MICROCONTROLLER BASED SINGLE CONTROL BOARD

Block diagram of the purposed microcontroller based single control board from the analysis of electricity Synchronization for Mea Kampong micro-hydropower plant project 3 to Provincial Authority grid System, Chiang Mai Thailand (2005) [17].

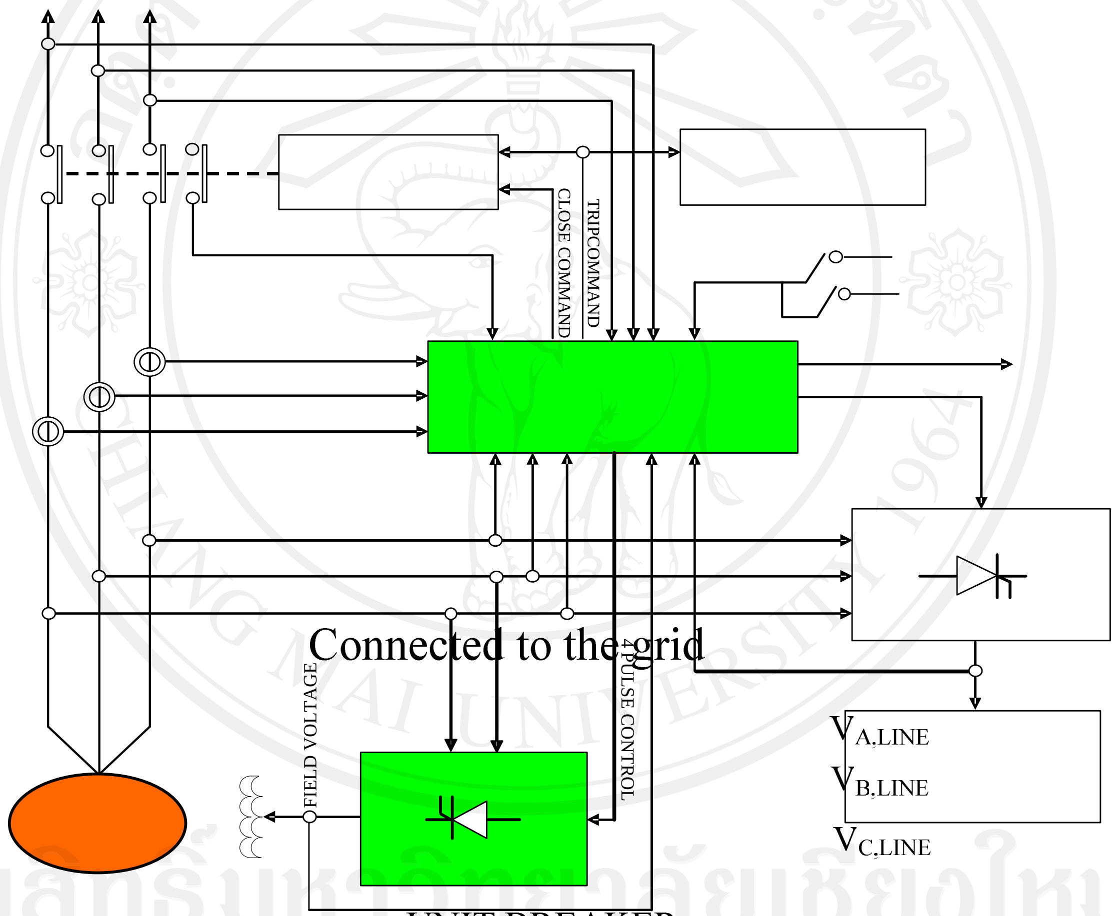


Figure A.6 Block diagram of the purposed microcontroller based single control board [17].

COST REFERENCE

Cost reference from the analysis of Benefit-Cost ratio of electricity Synchronization for Mea Kampong micro-hydropower plant project 3 to Provincial Authority grid System, Chiang Mai Thailand (2005) [17].

Table A.10 Cost of Equipments.

No	Items	Indexes	
		Bath	(US$)
1)	Synchronous component	120,000	3,600
2)	Guide Vance	20,000	600
3)	Control and Protection System	60,000	1,800
4)	Step-Up Transformer (50 kVA)	65,000	1,950
5)	Distribution line	16,250	500

Source: [17]

Table A.11 Installation Cost.

No.	Descriptions	Amount (US$)
1)	Transformer	400
2)	Electrical equipment	1,300
3)	Mechanical equipment	1,300

Source : [17]

APPENDIX B
THE INFORMATION OF STUDY FOR
NEW NAM DONG MICRO-HYDROPOWER PLANT

New Nam Dong micro-hydropower plant has been a conceptual design as an installation after the outlet by using the outflow rate of the existing Nam Dong small hydropower plant Nam Dong. In this part, more information of technical and economical aspect of the project is explained by the following :

B.1 General Information of the Project

B.1.1 Project Location

Nam Dong River is a relatively small river that is tributaries Mekong River. It flows through the south part of Luang Prabang district. The project is planned to locate in the middle of Nam Dong River. From Luang Prabang city center to the South available for reach to the site is about 40 minutes by car. The location map of the project is shown in the table B.1 and figure B.1

Table B.1 The Project Location.

Province	Luang Prabang
District	Luang Prabang
Village	Ban Xat
Distance	10 km from Luang Prabang city center, 40 minutes by car.

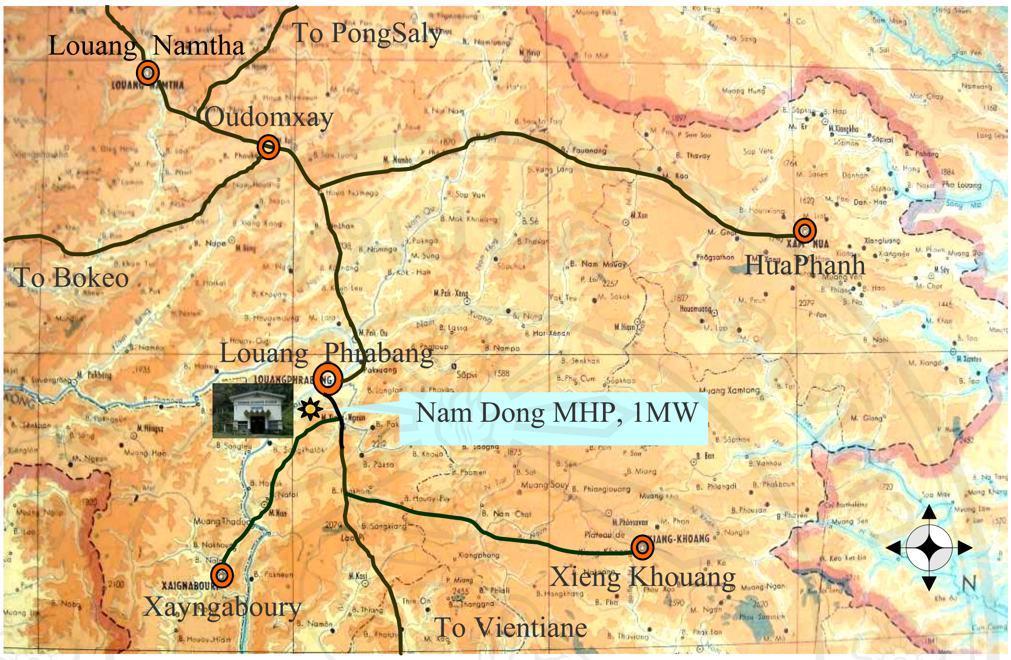


Figure B.1 The location of the existing Nam Dong Hydropower plant.

B.2 Concept Design of the New Nam Dong MHP.

The study New Nam Dong micro-hydropower plant is as a conceptual design. It is base on three main parts (1) water flow, (2) power generated, (3) operation and maintenance (O&M). The figure B.2 and B.3 presents the outline and the profile of new Nam Dong micro hydropower plant.

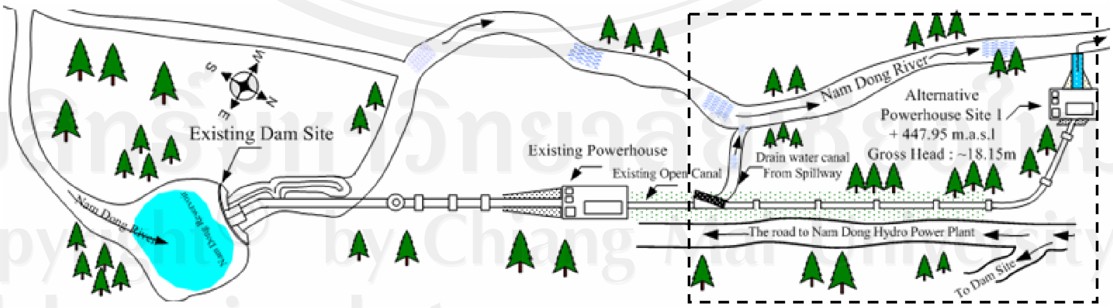


Figure B.2 The Outline of New Nam Dong MHP.

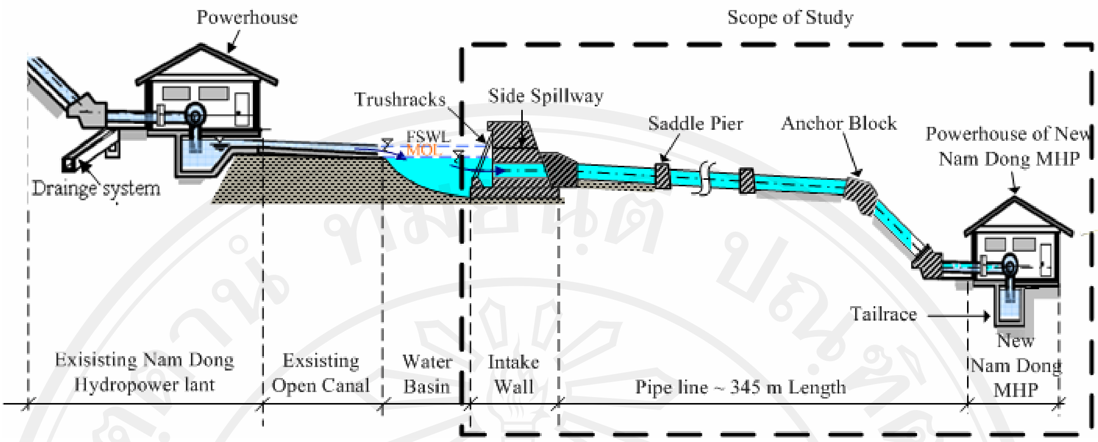


Figure B.3 The profile of new Nam Dong MHP, (Not to Scale).

1) The Work flow of the Project

The development a new micro-hydropower plant, the design for its facilities is as the conceptual design. The major works of this project present as follows:

a) Civil work includes the intake wall, powerhouse and the tailrace channel to return the water to the river,

b) Piping work includes layout pipe line and pipe support Piping work includes layout pipe line and pipe support**,**

c) Mechanical work includes turbine, water inlet control valve, and

d) Electrical work includes control panel and control system main transformer, transmission line for connection the electricity.

B.3 Works Description

B.3.1 Description of Civil Work

1) Intake Wall

The selection site and design intake is based on the location condition. The head work should be stable and suitable for reliable foundation. From the outline of New Nam Dong MHP shows in the figure B.3. The concrete intake wall will be planned to establish after existing Nam Dong hydropower plant by connecting to the tailrace canal. The potential location for construction the in take wall shown in figure B.4 and the simple characteristic of intake wall is expressed in figure B.5.

Figure B.4 The potential location of Nam Dong hydropower plant for construction Intake Wall (Photo, 2007)

a) Design the dimension of intake wall.

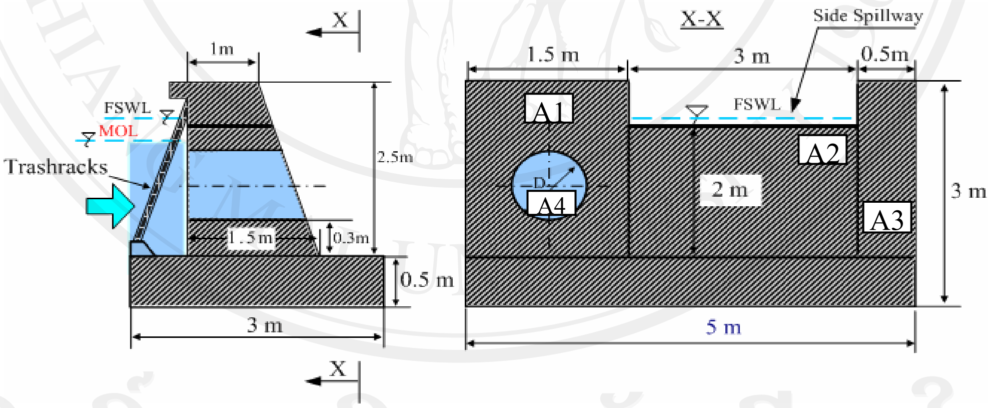


Figure B.5 The characteristic of Intake wall (Not to scale).

The dimension of the intake wall is based on the previous study. The height of intake wall is not less than the water depth between the Minimum Operation Level (MOL) and the center of inlet pipe [10]. The determination the dimension of intake wall is as follows :

- Inside pipe diameter 0.547 m
- Minimum Operation level $MOL = 0.3 + \left(\frac{D}{2}\right) + h$

Where, $h \geq \phi \quad in\ case\ of \quad (\phi < 1.0\, m)$

$h \geq \phi^2 \quad in\ case\ Of \quad (\phi > 1.0\, m)$

Therefore, *MOL = 0.3 + (0.574/2) + 0.574= 1.361 m*

The height of wall have to be greater than the MOL, it is therefore 2 m high. For easy calculation the volume concrete of intake wall, the thickness is assumed as a rectangle shape (see figure B.5.). It is expressed as follows:

The body of wall thickness	1.5 m
Length of wall	5 m
Total height (*H*)	3 m

Therefore, Cross section area at front view (X-X) is presented as follows:

Foundation

A0= (5x 0.5) m = 2.5 m^2

Wall body

A1= (1.5 x 2.5) m = 3.75 m^2

A2= (3 x 2) m = 6 m^2

A3 = (0.5 x 2.5) m = 1.25 m^2

$$A4 = \left(\frac{\pi D^2}{4}\right) = \left(\frac{\pi\, x\, 0.574^2}{4}\right) = 0.258\ m^2$$

Total Volume of Intake Wall is

(A0 x 3) + ((A1+ A2 +A3 -A4) x 1.5) = 23.613 m^3

The estimation cost of intake wall is based on its shape and total volume multiply by unit cost reference for concrete is 220 US$/$m^3$ [10] (See appendix E table E.3) .It is expressed by the following :

Cost of intake wall = 23.613 x 220 = 5,194 US$.

b) Trash rack

Trash rack will be planned to install at the entrance of the intake to prevent trash, leaves, and floating debris from flowing into the water. The design trash is depended on the recommendation and the experience from the studying of previous project [10].

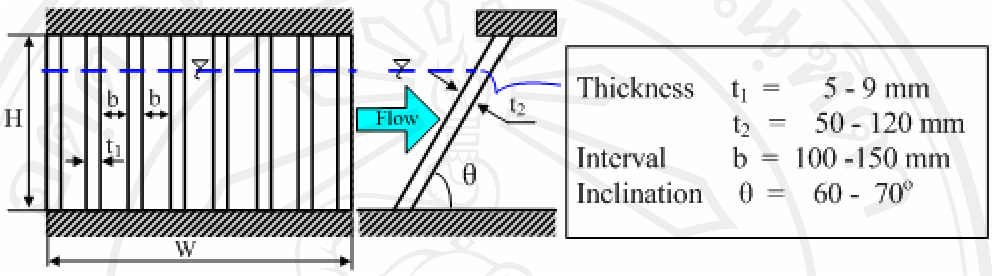


Figure B.6 Simple trash rack for Small-hydropower plant [10].

The determination the dimension of trash rack is based on the dimension of intake wall and the water inlet, It is designed by the following parameters :

Height	2.5 m
Width	2 m (Need the Number of bar 20 bars)
Interval (b)	100 mm
Thickness (t_1)	5 mm
Thickness (t_2)	100 mm

The estimate cost of steel trash rack is based on its total weight, and the unit cost of steel trash rack is 3,000 US$ /ton (See appendix E, table E.3) [10], thus cost of trash rack is calculated by the following:

The density of steel 7,850 kg/m^3, and

The total weight of trash rack is

[(0.005 x 20) x 2.5 x 0.1)] x 7,850 kg/m^3 = 196 kg.

Cost of trash rack = (196 kg x 3 US$/ kg) = 588 US$.

Therefore, the cost of intake work is

(5,194 US$ + 588 US$) = 5,782 US$

2) Powerhouse

The powerhouse is planned to locate at down stream of Nam Dong river side, 300 m far a way from the existing Nam Dong hydropower plant. The powerhouse structure is planned to design as same as the power station of Mea Ngut micro-hydropower project designed by EGAT. The dimension of powerhouse is width of 5 m and length of 8 m and the particular work parts are consisted of building structure, foundation of machine and water outlet. The figure B.7 and B.8 shows the section plan of powerhouse.

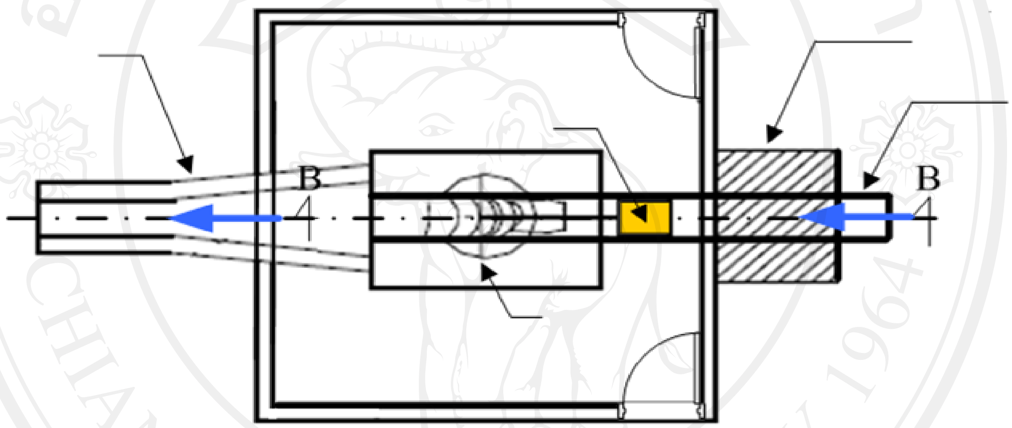


Figure B.7 Plan of the Power station.

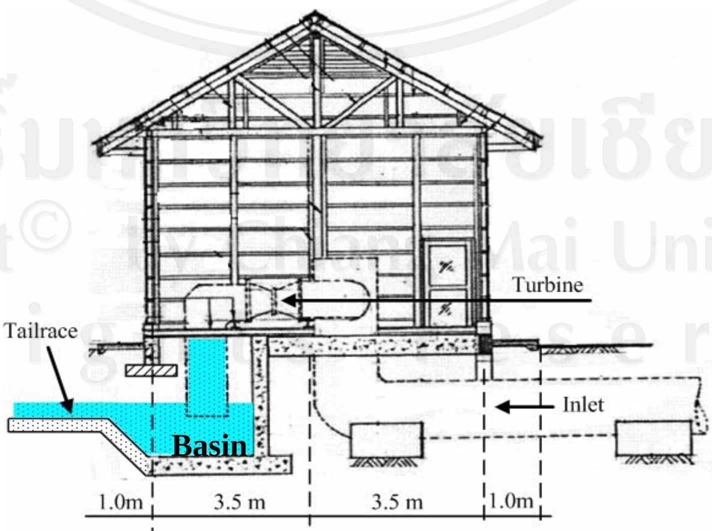


Figure B.8 Cross-Section of the Powerhouse (Mea Ngut MHP Project, 2007).

The estimation cost of powerhouse is based on the reference costs of Mea Ngut micro-hydropower project, 2007 which is an installed capacity 100 kW with the same type of turbine (See appendix D, table D.2) is used. Therefore, costs categories of powerhouse of the project are as follows:

Cost categories - Cost of Building Structure,
- Cost of water outlet basin,
- Foundation of machine and plant facilities, and

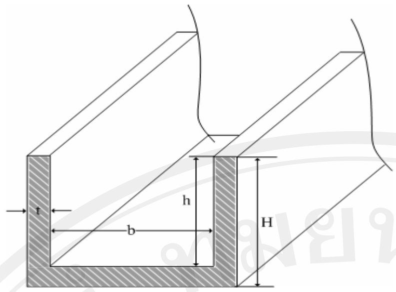
Total Cost of power house is 16,800 US$/100kW.

3) Tailrace

The tailrace is a channel which leads the water from the turbine back into the downstream of Nam Dong River. The location and simplified structures of tailrace will be planned. It is shown in the in figure B.9 and B.10.

Figure B.9 The potential location for installation Powerhouse and Tailrace

The tailrace canal will be planned as a rectangular shape concrete structure with breadth of (b=2.5 m), depth (h= 1.6 m) with wall thickness (t=0.3 m) and length (L=10 m). Based on the cost reference for concrete work 220 US$/$m^3$ [10], estimated cost of tailrace canal is expressed as follows:



Dimension of tailrace

b= 2.5 m
h= 1.6 m
t = 0.3 m
H= (1.6 + 0.3) = 1.9 m

Figure B.10 The characteristic of tailrace canal.

Cross-Section area

- Area 1 = (3.1 x 1.9) = 5.89 m^2
- Area 2 = (2.5 x 1.6) = 4 m^2

Annular cross section area A = (Area1-Area 2) = 1.89 m^2

Annular Volume V= 1.89 m^2 x 10 m = 18.9 m^3

Cost of tailrace canal 1.89 m^3 x 220 US$/$m^3$ = 4,158 US$

B.3.2 Piping Work

1) Selection the suitable Pipe Diameter

The considered suitable pipelines for New Nam Dong MHP project, the standard size of steel pipes from manufactures is used [22]. The length of the pipeline is approximately 345 m (See appendix B figure B.16). The steel pipe is used for the conceptual design. The determination the diameter of a pipeline is based on the water flow rate (maximum flow rate 0.88 m^3/s). The determination and selection the suitable pipe for the project are expressed in table B.2 and B.3.

Table B.2 The variation of pipe diameter at the water flow rate 0.88m^3/s

In term of friction loss with 100 meter Length.

Water Flow rate (m^3/s)	Inside Diameter ID (m)	Pipe Wall Thickness (mm)	Outside Diameter OD (m)	Weight Metric ton	Friction loss (m)	Power Loss P= γQH (kW)
0.88	0.381	4.953	0.386	2.342	3.494	30.132
0.88	0.428	5.070	0.433	2.691	1.980	17.077
0.88	0.457	5.143	0.462	2.916	1.145	9.874
0.88	0.574	5.435	0.579	3.865	0.449	3.871
0.88	0.737	5.842	0.742	5.327	0.129	1.113
0.88	1.00	6.500	1.007	8.041	0.080	0.69

Source : [22].

As seen in table B.2, there are various inside pipe diameters at the flow rate of 0.88m^3/s, each pipe diameter give the difference loss (head loss) due to friction between the moving fluid (water). To find out the suitable pipe diameter, the pipe weight and friction loss which is considered in term of power loss, was used to estimated costs of pipe and cost of annual energy loss respectively. The assumption parameter was setup.

Assumption parameters :

- Operation hours per year 8,760 hours.
- Electricity tariff 0.0563 US$/kWh [6]
- Unit cost of Penstock 4 kg/US4 [10]
- Discount factor 0.1175 at discount rate 10%
- Estimate project life 20 years.

There fore, cost of each pipe diameter and energy loss in term of annual worth can summary in the table B.3

Table B.3 Cost of pipe diameter and energy loss in variation of pipe diameter at the water flow rate 0.88m^3/s, 100 m length in term of annual worth.

Water Follow rate (m^3/sec)	Inside Diameter ID (m)	Pipe Wall Thickness (mm)	Weight		Annual energy loss	
			Metric ton	US$/year	kWh	US$
0.88	0.381	4.953	2.342	1,254.08	263,953	14,861
0.88	0.428	5.070	2.691	1,441.34	149,591	8,422
0.88	0.457	5.143	2.916	1,561.42	86,494	4,870
0.88	0.574	5.435	3.865	2,069.96	33,914	1,909
0.88	0.737	5.842	5.327	2,852.57	9,754	549
0.88	1.000	6.500	8.041	4,306.10	6,044	340

Source: [22].

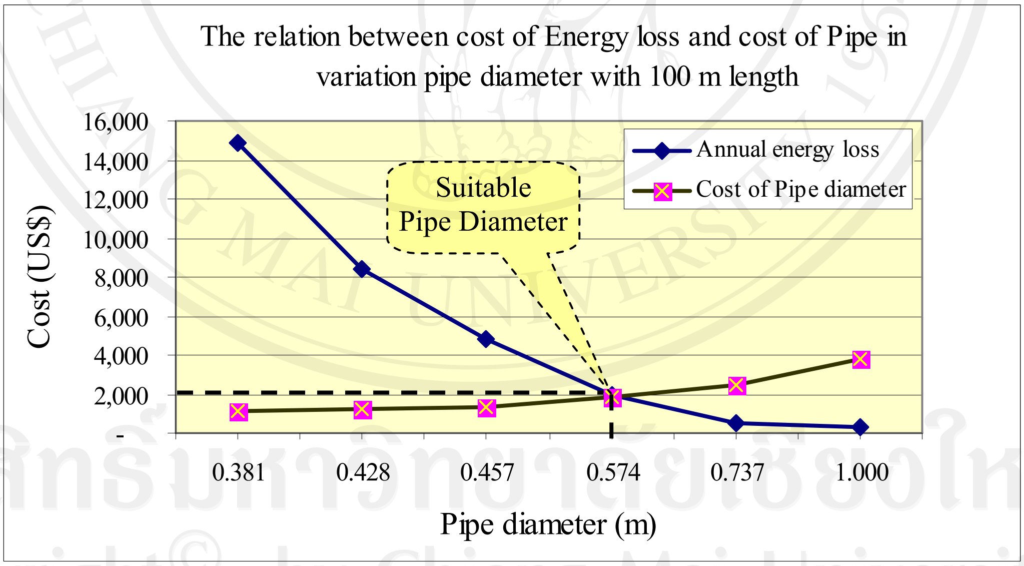


Figure B.11 The relation between cost of energy loss and cost of pipe in variation pipe diameter.

As seen in figure B.11, it indicated that the suitable pipe diameter could select with the intersection between cost energy loss and cost of pipe in terms of annual worth. To reduce the loss and to meet the diameter of inlet vale of 600 mm [8] connected turbine inlet. Selection the suitable pipe diameter, the standard size of steel pipes from manufactures is used and can summarize as follows [22].

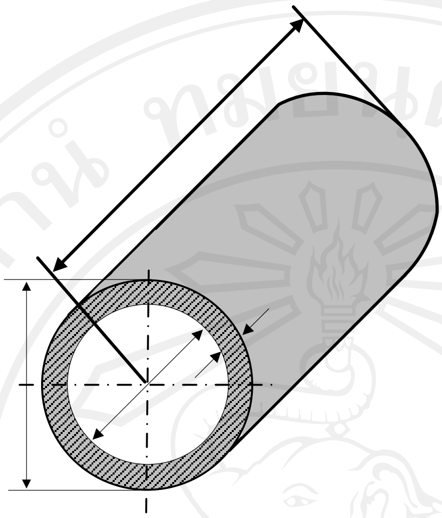


Figure B.12 the characteristic of pipe diameter.

Specification of the pipe

- Type of pipe Wrought Iron or Schedule 40 Steel Pipe,
- Inside Pipe Diameter 574 mm or 0.574 m
- Friction loss 0.44 m at 100 m length.

2) Estimate Cost of Piping Work

The design pipe is not only based on the standard size from manufacture but also considered for convenient of transportation to the site and easy for installation, the length of pipe is designed 9 m. The estimated cost of piping work is based on the weight of which is calculated by pipe diameter and the pipe wall thickness. The cost reference for steel pipe is 4,000 US$/ton (See appendix E, table E.3) [10]. It is expressed by the following:

a) The suitable pipe parameters

- Length of steel pipe *(L)* 9 m,
- Inside pipe diameter *(ID)* 574 mm or 0.574 m,
- Steel density 7,850 kg/m^3

The water pipe will be above ground the minimum thickness for fabricates and handing is calculated by the equation follows [10]:

$$t = \left(\frac{d + 800}{400}\right) + 2\,(mm) \qquad \text{(B.1)}$$

Where, d: Inside pipe diameter (mm)

$$\text{Therefore, Wall pipe thickness} = \left(\frac{574 + 800}{400}\right) + 2 = 5.435\,mm$$

According to the thickness steel standard was recommended [22]. The pipe thickness of 6 mm with the length of 9 m is used. The weight of can compute as follows :

- Inside Pipe diameter *(ID)* 574 mm,
- Pipe wall thickness *(t)* 6 mm,
- Outside Pipe diameter *(OD)* (574 +6) = 580 mm.

Cross section area of Pipe wall thickness

$$A = \left(\frac{\pi D^2}{4} - \frac{\pi d^2}{4}\right)^2 = \frac{\pi}{4} \times \left(0.580^2 - 0.574^2\right) = 0.005\,m^2$$

The annular weight of pipe (W_p) with 9 m Length.

W_P= A x L x 7,850 = (0.005 m^2 x 9 m x 7,850 kg/m^3) = 353.25 kg

From site investigation, the project has the total length of pipe 475 m from the intake to the turbine inlet. The unit cost of penstock is 4US$/kg recommended by the cost reference (see appendix E, table E.3) [10]. Estimated cost of pipe is expressed by the following:

$$\text{Total amount of Pipe} = \left(\frac{345}{9}\right) = 38\ piesces.$$

Unit cost of pipe at 9 m length = 353.25 kg x 4 US$/kg = 1,413 US$

Total cost of pipe = 38 Pieces x 1,413 US$ = 53,694 UD$

b) Pipe support

In general, the pipe support for the small hydropower plant is consisted of two types (the details are shown in figure B.13).

(i) Saddle pier are provide at 10m interval and,

(ii) Anchor block should be provided less than 100 m interval.

The design pipe support is based on outside pipe diameter. The pipe support amount depends on the total length of pipe of 345 m. The simplify structure of pipe supports were considered by recommendation from previous project. The design pipe support shown in figure B.13 and the needed number is as follows :

Anchor block	30 pieces
Saddle pier	5 Pieces

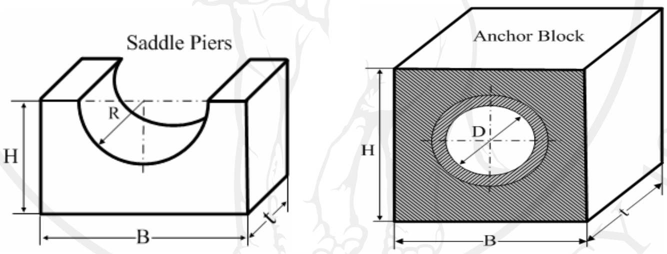


Figure B.13 The characteristic of the pipe support.

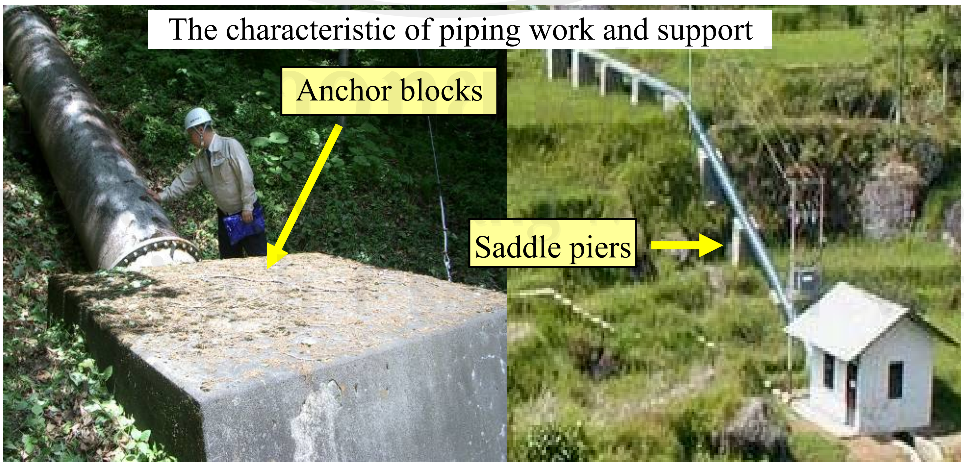


Figure B.14 the characteristic of the pipe support [10].

From the recommendation of previous project of small-hydro power plants and many experience of the EGAT for micro-hydropower project, the cost of pipe support is approximately taken 15% of the total cost of pipe [10]. Therefore, the costs of piping work are summarized as follows:

The cost of Pipe support = (53,694 US$ x 0.15) = 8,054 US$

Total Cost of piping work = (53,694 US$ + 8,054 US$) = 61,748 US$

B.4 Determination Effective Head (H_e)

The effective head is the gross head by deduction the head losses between the intake and tailrace are expressed as follow:

$$\text{Effective Head} \quad (H_e) = H_g - H_{Loss}$$

Where, H_g : Grosses Head (m),

H_{Loss}: Head Loss (m),

(H_{Loss} = *Major Head loss - Minor Head Loss*).

Energy losses (Head Loss) consist of major loss and minor loss, i.e., major loss is due to friction between the moving water and the inside walls of the duct and minor loss is due to fittings such as valves and elbows. The calculation head losses are based on pipe diameter and pipe length. By mean while the losses decrease substantially with increasing pipe diameter.

1) Major Head Loss

For determining the major head loss the Darcy- Weisbach Chapter 2, Equation 2.6 is used:

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

Where, f: Moody friction factor,

L: Total pipe length (m),

D: Inside pipe diameter (m),

V: Fluid velocity in the pipe (m/s),

g: accelerated gravity (g = 9.81 m/s^2).

In order to the major loss (friction loss) mentions with the standard size of steel pipes from manufactures shown in table B.3. The major can calculate as follows:

- Total pipe length	345 m
- Type of pipe	Wrought Iron or Schedule 40 Steel Pipe
- Inside Pipe Diameter	574 mm or 0.574 m
- Friction loss	0.44 m at 100 m length

Therefore

The Major loss is (0.44 m x 3.45) = 1.5 m of 345 m Length.

2) Minor Head Loss (h_m)

The minor head loss consists of loss at trash rack, penstock inlet, loss due to bend, inlet valve and etc. The minor loss is calculated by the equation 2.9, Chapter 2.

$$h_m = k\frac{v^2}{2g} \quad \text{(m)}$$

Where

k: Minor Loss Coefficient (Unit-Less)

V: velocity (m/s).

Determine the velocity

Form the equation $Q = V \times A \quad (m^3)$

Where, Q= 0.88 m^3/s, and Inside Pipe diameter 0.547 m

$$V = \frac{4Q}{\pi D^2} = \frac{4\times 0.88}{\pi \times 0.547^2} = 3.7\ m/s$$

As seen in the figure B.3 and B.3, The minor loss coefficient (k) during the intake to the inlet of turbine is integrated by the following [20]:

- Entrance Loss 1 x 0.15 = 0.15
- Loss due to bend 2 x 0.11 = 0.22
- Loss due to gate Valve (Pipe fitting) 2 x 0.19 = 0.38
- Loss due to gradual contraction 1x 0.036 = 0.036

Coefficient *(k)* = (0.15 + 0.22 + 0.38 + 0.036) = 0.786 (Unit less)

$$\text{Minor loss} = 0.786 \times \frac{3.7^2}{2 \times 9.81} = 0.54 \text{ m}$$

Therefore, total head loss of this project is

Head Loss = 1.5 4 m+ 0.54 m = 2.08 m

The effective head is the gross head (19.15 m) by deduction the head loss (2.08m) as follows:

Effective Head (H_e) = 19.15 m -2.08 m = 17.07 m

From the results of study the technical feature potential was summarized in table B.4.

Table B.4 Summary of technical features potential of the project.

Data	Indexes
Maximum water flow rate	0.88 m^3/s
Gross head	19.15 m
Total pipe length	345 m
Type of pipe	Wrought Iron
Suitable Inside Pipe diameter	0.574 mm
Pipe Thickness	6 mm
Head Loss	2.08 m
Effective Head	17.07 m

B.5 Ecnomic Evaluation

The evaluation of the economic viability of the project in variation the discount rate at the electricity tariff of 0.0563 US$/kWh is demonstrated in table B.5.

Table B.5 Economic Net cash flow of the porject

Year	Cost of Project (C)			Benefit			Net Cash Flow (B+C) (US$)	Discount factor at discount rate 10%	NPV of Net Cash Flow (US$)
	Capital Cost (US$)	Cost of O&M							
		Yearly Inspection (US$)	Spare Parts (US$)	Energy generation (kWh/year)	Electricity tariff (US$/kWh)	Amount (US$)			
0	(227,150)						(227,150)		(227,150)
1	-	(1,622)		575,769	0.0563	32,416	30,794	0.9091	27,994
2	-	(1,695)		575,769	0.0563	32,416	30,721	0.8264	25,389
3	-	(1,771)		575,769	0.0563	32,416	30,645	0.7513	23,024
4	-	(1,851)		575,769	0.0563	32,416	30,565	0.6830	20,876
5		(1,934)	(1,770)	575,769	0.0563	32,416	28,712	0.6209	17,828
6	-	(2,021)		575,769	0.0563	32,416	30,394	0.5645	17,157
7	-	(2,112)		575,769	0.0563	32,416	30,304	0.5132	15,551
8	-	(2,207)		575,769	0.0563	32,416	30,208	0.4665	14,092
9	-	(2,307)		575,769	0.0563	32,416	30,109	0.4241	12,769
10		(2,410)	(1,770)	575,769	0.0563	32,416	28,235	0.3855	10,886
11	-	(2,519)		575,769	0.0563	32,416	29,897	0.3505	10,479
12	-	(2,632)		575,769	0.0563	32,416	29,784	0.3186	9,490
13	-	(2,751)		575,769	0.0563	32,416	29,665	0.2897	8,593
14	-	(2,875)		575,769	0.0563	32,416	29,541	0.2633	7,779
15		(3,004)	(1,770)	575,769	0.0563	32,416	27,642	0.2394	6,617
16	-	(3,139)		575,769	0.0563	32,416	29,277	0.2176	6,371
17	-	(3,280)		575,769	0.0563	32,416	29,136	0.1978	5,764
18	-	(3,428)		575,769	0.0563	32,416	28,988	0.1799	5,214
19	-	(3,582)		575,769	0.0563	32,416	28,834	0.1635	4,715
20	-	(3,743)		575,769	0.0563	32,416	28,672	0.1486	4,262
								Total	**27,700**

Results : Incase of a variation the discount rate in range (8% to 15%).				
Discount Rate	8%	10%	12%	15%
1) NPV of Net Cash Flow (US$)	66,167	27,700	(3,139)	(38,955)
2) Internal Rate of Return (IRR) (%)	12%	12%	12%	12%
3) Benefit-Cost Ratio (B/C)	1.28	1.12	0.99	0.99
4) Payback Period (Years)	12.00	14.79	-	-
5) Unit Energy Cost (US$/kWh)	0.0441	0.0502	0.0566	0.667

Table B.5 (Continued)

Results : Incase of an increment the project cost of 227,150 US$ and discount rate 10%.					
Percentage of increment (%)	Base Case	10%	20%	30%	40%
Cost of increment (US$)	227,150	249,865	272,580	295,295	318,010
1) NPV of Net Cash Flow (US$)	27,700	4,985	(17,730)	(40,445)	(63,160)
2) Benefit-Cost Ratio (B/C)	1.12	1.03	0.95	0.88	0.82
3) Internal Rate of Return (IRR) (%)	12%	10%	9%	8%	7%
4) Payback Period (years)	14.79	18.85	-	-	-
5) Unit Energy Cost (US$/kWh)	0.0502	0.0548	0.0595	0.0641	0.0687

The economic results shown in the table B.6, at the discount rate of 10%, the project cost of 227,150 US$, and the electricity tariff of 0.0563 US$/ kWh the project could be economically acceptable. The determination Benefit-Cost ratio (B/C) and Payback period will be expressed as follows :

As a term of the energy generation potential was 575,769 kWh/year, discount rate was 10% electricity tariff was 0.0563 US$/kWh, the example of a determination Benefit-Cost ratio (B/C) is expressed as follows :

1)	Project Life	20 Years
2)	Capital Recovery Factor	0.1175
3)	Initial Investment cost	227,150
4)	Annual worth of investment Cost	26,681
5)	Annual maintenance cost in Annual worth	2,222
6)	Annual worth of benefit	32,416
7)	Disbenefit	0

$$B/C = \frac{Benefit - Disbenefit}{Costs}$$

$$B/C = \frac{32{,}416 - 0}{26{,}681 + 2{,}222}$$

Therefore, $B/C = 1.12$

The Payback period (n_p) of the project at the project cost of 227,150 US$, the potential energy recovery of 575,769 kWh/year, electricity tariff of 0.0563 US$/kWh and discount rate (DR) was 10% is calculated by the following expression:

From equation 2.17, Chapter 2 : $0 = -P + \sum_{t=1}^{t=n_p} NCF_t \left(P/F, r, t\right)$

1) Initial Investment cost is 227,150 US$,

From the table B.5 the summation of the NPV of Net cash flow during the th-year (14th and 15th). They were expressed by the following :

$$\sum_{t=1}^{t=14} NCF_t \left(P/F, 10\%, t\right) = 221{,}907\, US\$ < 227{,}150 US\$$$

$$\sum_{t=1}^{t=15} NCF_t \left(P/F, 10\%, t\right) = 228{,}524\, US\$ > 227{,}150 US\$$$

The Pay back period was available 14-15-th year; the number of year required to recover the investment. It will be defined by the interpolation method.

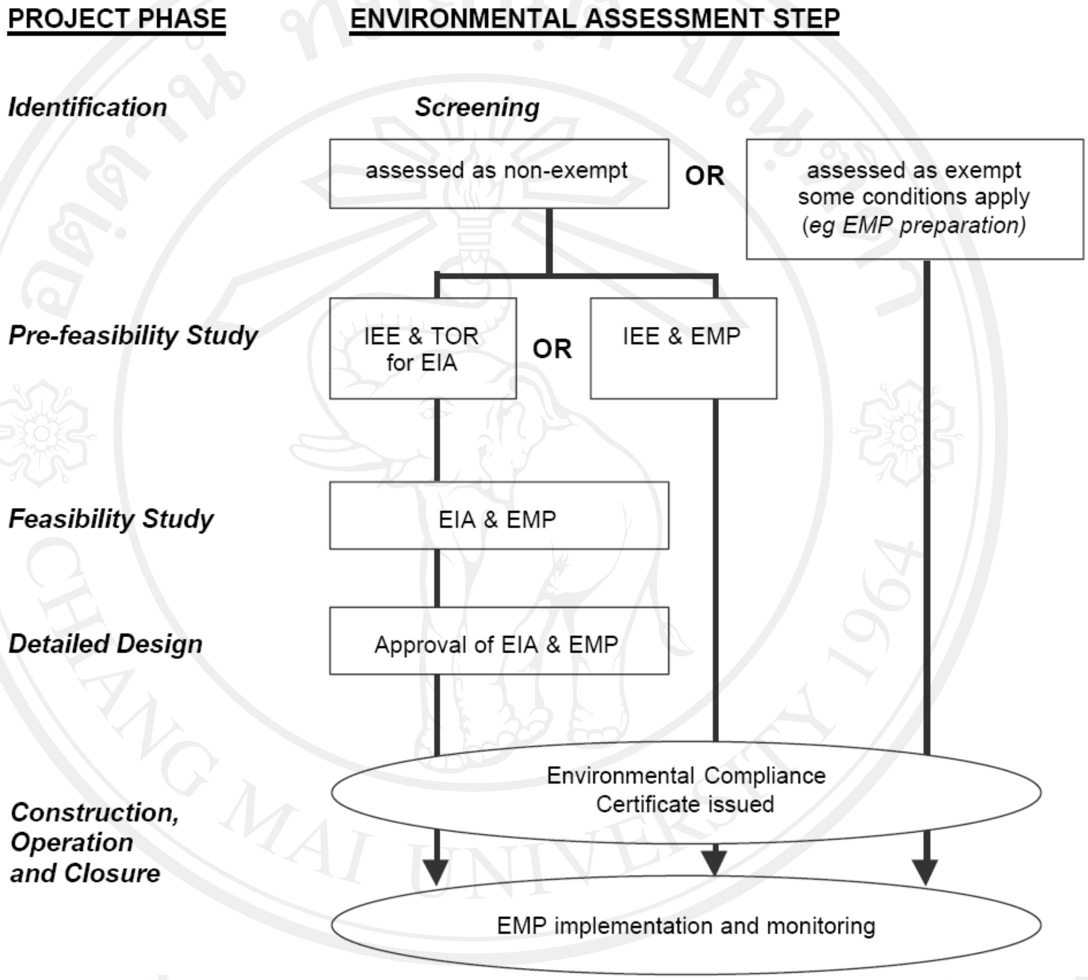
$$\frac{227{,}150 - 221{,}907}{228{,}524 - 221{,}907} = \frac{n - 14}{15 - 14}$$

$$n = 14.79$$

Therefore, Pay back Period of the project was 14.79 year(s).

B.6 Environmental Assessment Step

The environmental assessment process is based the master plant study on small hydropower in Laos PDR. The step of assessment are shown in the figure B.15.



Source: Derived from Regulation on Environment Assessment, 2000

EMP – Environmental Management Plan

EIA – Environmental Impact Assessment

TOR – Terms of Reference

Figure B.15 Regulation Defined Environmental Assessment Process [10]

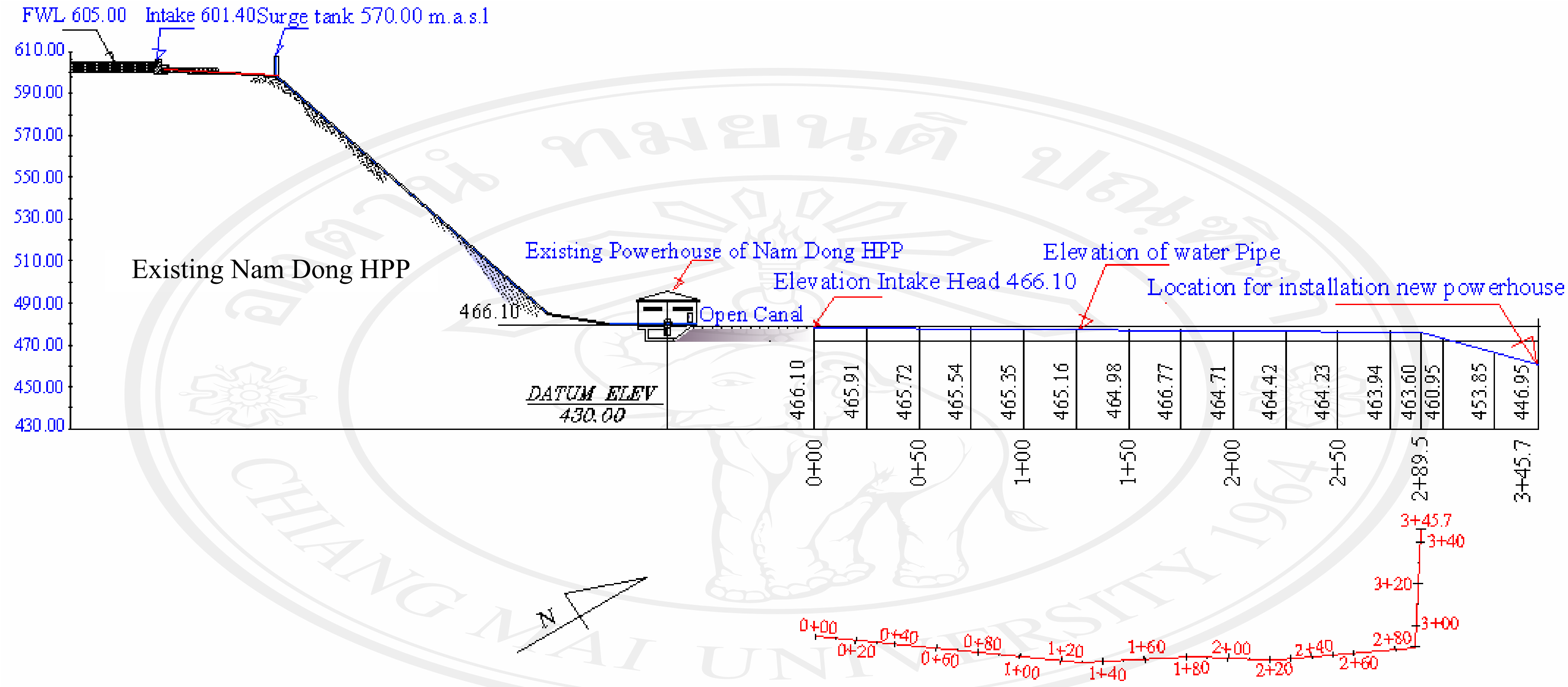


Figure B.16 The out line of elevation and distance from intake to powerhouse (Site reconnaissance March, 2007)

1) Gross head	(466.10- 446.95) m.a.s.l = 19.15m,
2) Distance (from intake to power house)	289.5 m,
3) Length of pipe line (From Intake to Powerhouse)	approx. 345.7 m.

APPENDIX C
THE INFORMATION OF STUDY FOR
EXISTING NAM PHA MICRO-HYDROPOWER PLANT

C.1 Introduction

Nam Pha micro-hydropower plant (18kW) was built in 1998 by the donation of Mini Promotion for Local Project (European Union), and under authority of Ministry of Agriculture and Forest of Lao PDR. The main objective of this project is for both multipurpose system such as irrigation and electricity supply.

C.2 General Information of Nam Pha MHP

C.2.1 Project Location

Nam Pha micro-hydropower plant (MHP) locates in the middle of Nam Pha River, The location of the project is described in the table 5.1 and figure C.1.

Table C.1 The Location of Nam Pha MHP.

Province	Luang Prabang
District	Luang Prabang
Village	Kok Vanh
Distance	About 30 km from Luang Prabang City center, one hour by car to the

Figure C.1 The location map of Nam Pha MHP.

C.2.2 Justification of Nam pha MHP

1) The Profile of Electricity Supply

Since commissioning 1998, Nam Pha micro-hydropower project has been only supplied electricity one village named Ban Kovhanh in Luang Prabang district where is consisted of 150 households. The operation hour is 12 hours (from 6.00 a.m. to 18.00 p.m.) during dry season and operates 5 hours more (from 18.00 p.m. to 23.00 p.m.) during rainy season.

2) Project Description

The Nam Pha micro-hydropower Plant has a total capacity of 18 kW; with energy output is approximately 22,200 kWh/year, the physical of the plant is explained in table C.2.

Table C.2 The general features of Nam Pha MHP.

No	Items	Unit	Description
1	Name of Plant		Nam Pha
2	Construction completed		1998
3	Design and Constructed by		Electricity company of China
5	Installed Capacity	kW	18 kW (20 kVA)
6	Annual production	kWh/year	22,780
7	Construction Cost	US$	85,000
8	Electricity tariff	US$/kWh	0.066 US$/kWh
9	Number of operators		3 people
	Number of operating hours		10 to 12 hours
10	Intake gate		
	Type of intake		De-silting basin
	Intake structure		Steel Gate and Manual Regulator
	Height x Width	m	2 x 1.2
11	Water Way		
	Type of waterway		Non-pressure type Open Canal
	Width x depth x Length	m	3 x 2 x 490
12	Forebay tank (Head tank)		
	Type of head tank		Rectangle
	Structure		Concrete
	Height x Width x Length	m	2 x 2.5 x 15
13	Penstock		
	Type of penstock		Steel
	Number of penstock	1	9 m length
	Inner diameter	m	0.5
	Length	m	9
14	Power House		
	Type of power house		Above ground
	Structure		Stone Masonry

Table C.2 (Continued).

	Height x Width x Length	m	3.5 x 5.0 x7.0
15	Outlet (Tailrace)		
	Type		Open Channel
	Structure		Concrete
	Wall Thickness	m	0.3
	Height x Width x Length	m	1.0 x 1.0 x 15
17	Turbine	kW	Disable
	Gross head	m	5.5
	Effective (Net) head	m	5.2
	Type of turbine		Francis Vertical Shaft
	Unit capacity	kW	1 x 18 kW (20kVA)
	Design discharge	m^3/s	0.58
18	Generator		Disable
	capacity	kVA	20
	Type of generator		Synchronous generator
	Rate speed	r/min	1,000~1,800
	Output voltage	V	Three Phase 400 V
19	Transformer		Disable
	Transformer capacity	kVA	25
	Ratio	kV	0.4/11
	Frequency	Hz	50-60
20	Transmission Line		Disable
	Length	km	1.6
	Voltage	kV	11 kV
21	Distribution Line		Disable
	Length	km	3
	Voltage	kV	0.4

C.3 The Activities of Study

From the previous data information of Nam Pha MHP in such that its technical data is used for rehabilitation purpose that is considered without enlargement the scale of the project. Based on the real condition of the project, plant structures will be modified.

C.3.1 The Work flow of the Project

After site visited, the rehabilitations scheme of the project is proposed by the concept of modification with the simplify plant structure, easy to operate, maintain and minimize cost. The work flow is as follows :

a) Modify intake structure,

b) Replace earth canal with steel pipe,

c) Reconstruction for powerhouse,

d) Chang the part of mechanical work, i.e., turbine and control system,

e) Change for new electrical equipment such as generator, transformer and control system, and

f) Install new distribution line.

C.3.2 System Design of Nam Pha MHP

The outline for new plant structures of Nam Pha MHP project by modification the plant structure is shown in figure C.2.

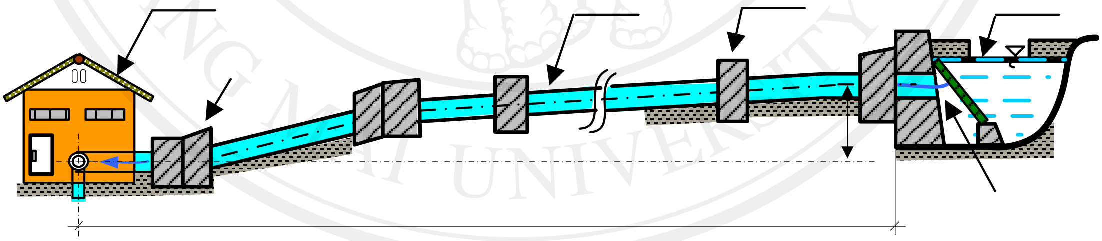


Figure C.2 The profile for installed the plant facilities of Nam Pha MHP.

1) Description of the Civil Work

Civil structures control the water that runs throughout hydropower system, and conveyances are a large work part of the project. It should be located in suitable sites and designed for optimum performance and stability to reduce cost and ensure a reliable system.

a) Intake wall

The concept of minimize the cost and simplify design structure, the concrete wall will be planned to establish downstream of the existing bed of the irrigation canal. It is designed for ensure supply the water to the turbine and protect debris flow through intake (See figure C.2). The estimation cost of the intake wall is based on the cost reference of the study the simplified intake structure of the existing micro-hydropower projects in Northern Province of Lao PDR [10]. The potential location for installation the intake wall and the structure of intake wall are shown in the figure C.3 and C.4.

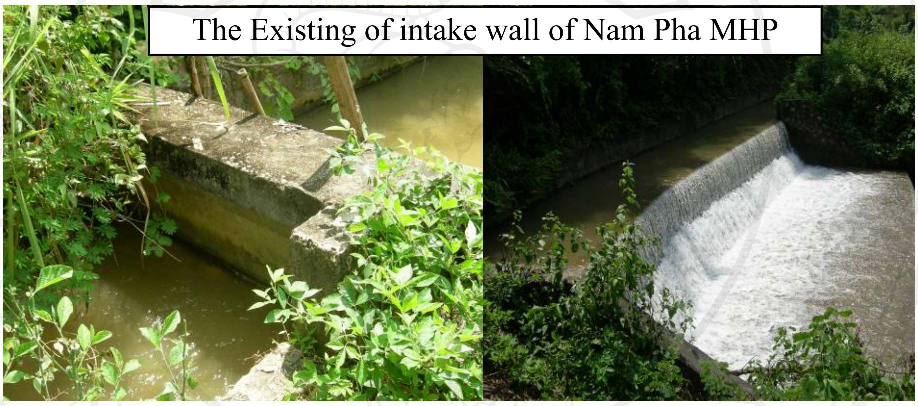


Figure C.3 The Potential Location for installation the Intake wall.

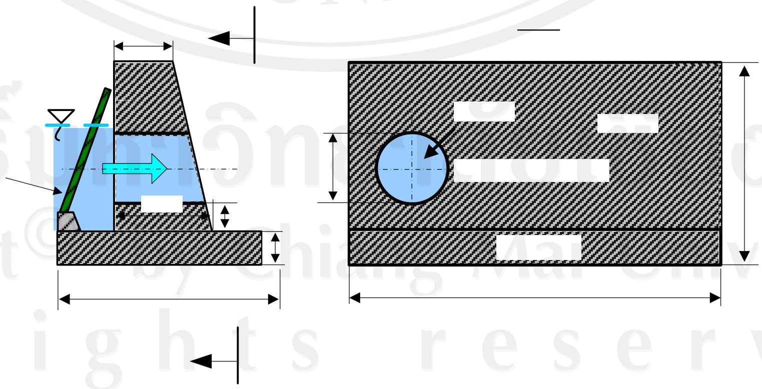


Figure C.4 The characteristic of Intake wall (Not to scale).

The dimension of the intake wall is based on the previous study. The height of intake wall is not less than the water depth between the Minimum Operation Level

(MOL) and the center of inlet pipe [10]. The determination the dimension of intake wall is as follows :

Inside pipe diameter 0.478 m

Minimum Operation Level $(MOL) = 0.3 + \left(\frac{ID}{2}\right) + h$

Where, $h > \phi$ *in case of* $(\phi < 1.0\,m)$

$h > \phi^2$ *in case of* $(\phi > 1.0\,m)$

ϕ: Inside pipe diameter (ID)

Therefore *MOL = 0.3 + (0.478/2) + 0.478= 1.07 m.*

The height of have to be is greater than the MOL, it is therefore 2 m high. For easy calculation the volume concrete of intake wall, the thickness is assumed as a rectangle shape (see figure C.4). It is expressed as follows:

- The body of wall thickness is 1 m
- Length of wall is 3 m
- Height of wall is 2 m

Cross section area at front view (X-X) see figure C.4.

- Foundation

Area 1 = (0.5 m x 3 m) = 1.5 m^2

- Wall body

Area 2 = (2 m x 3 m) = 6 m^2

Area 3 = $\left(\frac{\pi D^2}{4}\right) = \left(\frac{\pi \times 0.478^2}{4}\right)$ = 0.179 m^2

Total Volume of Intake Wall:

(Area 1 x 1.5 m) + ((Area 2- Area 3) x 1 m) = 7.3 m^3

The estimation cost of intake wall is based on its shape and total volume multiply by unit cost reference for concrete is 220 US$/$m^3$ [10] (See appendix E table E.3) .It is expressed by the following :

Cost of Intake Wall = 7.3 m^3 x 220 US$/$m^3$ = 1,600 US$

Trash rack will be planned to install at the entrance of the intake to prevent trash, leaves, and floating debris from flowing into the water. The design trash is depended on the recommendation and the experience from the previous project.

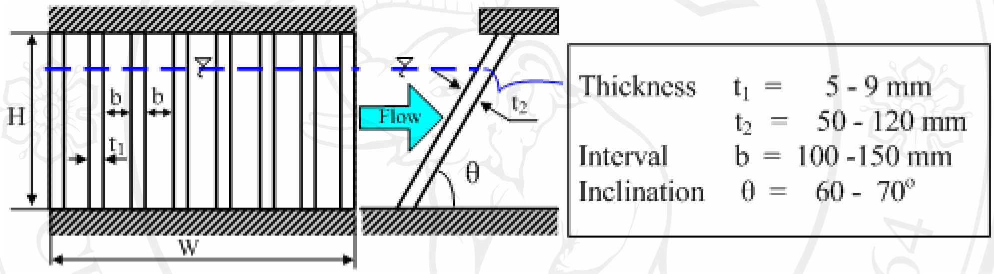


Figure C.5 Simple trash rack for small hydropower plant [10].

The dimension of steel trash rack is design by the following parameters :

- Height	1.5 m	
- Width	1.5 m	(Need the Number of bar 15 bars)
- Interval (b)	100 mm	
- Thickness (t_1)	5 mm	
- Thickness (t_2)	100 mm	

The estimate cost of trash rack is based on the total weight, and the unit cost reference is 3,000 US$ /ton (see appendix E, table E.3) [10], thus cost of trash rack is calculated by the following :

- The density of steel 7,850 kg/m^3, and

- The total weight with dimension is

Total Weight = Cross section area x t_2 x 7,850 kg/ m^3 (kg)

Total Weight = ((0.005 m x 17 bars) x 1.5 m x 0.1 m)) x 7,850 kg/m^3 = 100 kg.

- Cost of trash rack = (100 kg x 3 US$/ kg) = 300 US$

Therefore, the cost of intake work is (1,600 US$ + 300 US$) = 1,900 US$

b) Powerhouse and Tailrace

Based on the real condition of the existing powerhouse (See in figure C.5), The new above ground type of powerhouse will be planned to build higher than water level of Nam Pha River during flood.

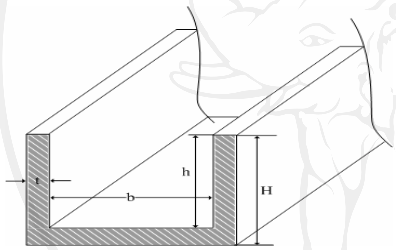
Figure C.6 Powerhouse of Nam Pha MHP.

The estimation cost of powerhouse and tailrace of the project is based on the cost formulas for quick cost estimate for the study on small hydropower plant in Laos [10] (see appendix E, table E.2). It is expressed as follows:

Cost of powerhouse = Installed capacity (kW) x Unit Cost (US$/kW)

18 kW x 200 US$/kW = 3,600 US$.

Based on the previous design (See table C.2), the rectangular concrete structure tailrace with the dimension, i.e., breadth of (b =1.3 m), depth (h = 1.3 m) with wall thickness (t = 0.3 m) and length (L =15 m) is designed. [10]. The estimation cost of tailrace canal is expressed as follows:



Dimension of tailrace

b= 1.0 m
h= 1.0 m
t = 0.3 m
H= (1.0 m+ 0.3 m) = 1.3 m

Figure C.7 The characteristic of tailrace canal.

Cross Section areas

- Area 1 = (1.6 m x 1.3 m) = 2.08 m^2
- Area 2 = (1 m x 1 m) = 1 m^2

Annular cross section area A = (Area1-Area 2) = 1.08 m^2

Annular Volume V = 1.08 m^2 x 15 m = 16.2 m^3

Cost of concrete work 220 US$/$m^3$ [10]

Therefore, Cost of tailrace canal 16.2 m^3 x 220 US$/$m^3$ = 3,564 US$

2) Piping Work

a) Estimated Suitable Pipe Diameter

Based on the water flow rate 0.58 m^3/s, there is various pipe diameters recommendation standard size of steel pipes from manufacture [22]. They are shown in table C.3.

Table C.3 The variation of pipe diameter at the water flow rate $0.88m^3/s$ in term of friction loss with 100 m length.

Water Flow rate (m3/sec)	Inside Diameter ID (m)	Pipe Wall Thickness (mm)	Outside Diameter OD (m)	Weight Metric ton	Friction loss (m)	Power Loss P= γQH (kW)
0.58	0.303	4.076	0.307	1.534	4.907	27.890
0.58	0.333	4.083	0.337	1.689	3.028	17.209
0.58	0.381	4.095	0.385	1.934	1.524	8.664
0.58	0.429	4.107	0.433	2.181	0.842	4.787
0.58	0.478	4.119	0.482	2.438	0.484	2.749
0.58	0.575	4.144	0.579	2.947	0.192	1.09

Soucre : [22].

From table C.3, each pipe diameter give the different losses (head loss) due to friction between the moving fluid (water) and inside walls of the pipe, so to find out the suitable pipe diameter, the pipe weight and friction loss which considered in term of power loss, was used to estimate cost of pipe and cost of annual energy loss respectively. The assumption parameter was setup :

Assumption parameters

- Operation hours per year is 8,760 hours/year,
- Electricity tariff is 0.0385 US$/kWh [6],
- Unit cost of Penstock is 4 kg/US$ [10],
- Discount factor is 0.1175 at discount rate 10% and
- Estimate project life is 20 years.

There fore, cost of each pipe diameter and energy loss are estimated in term of annual worth for considering the pipe diameter and can summarize in the table C.4.

Table C.4 Cost of pipe diameter and energy loss in variation of pipe diameter at water flow rate 0.58m^3/s, 100 m length in term of annual worth.

Water Flow rate (m^3/s)	Inside Diameter ID (m)	Pipe Wall Thickness (mm)	Weight		Annual energy loss	
			Metric ton	Annual cost (US$/year)	(KWh)	(US$)
0.58	0.303	4.076	1.534	450.51	244,319	13,755
0.58	0.333	4.083	1.689	495.97	150,750	8,487
0.58	0.381	4.095	1.934	568.00	75,895	4,273
0.58	0.429	4.107	2.181	640.53	41,933	2,361
0.58	0.478	4.119	2.438	715.88	24,085	1,356
0.58	0.575	4.144	2.947	865.38	9,547	538

Soucre : [22].

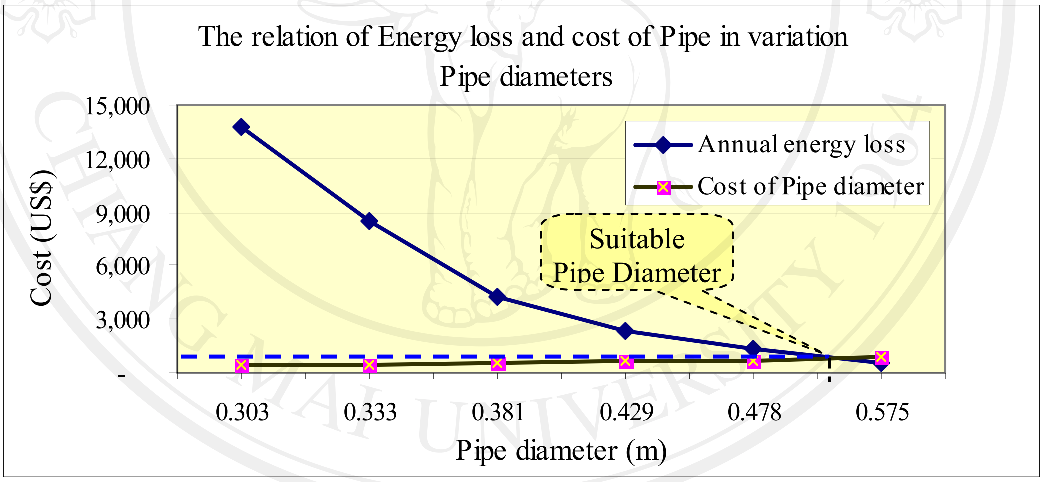
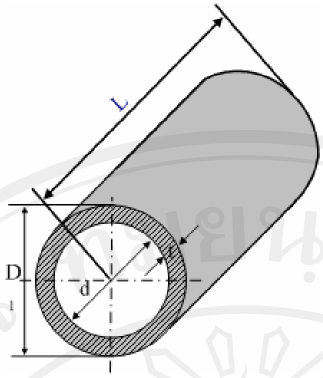


Figure C.8 The relation of cost of energy loss and cost of pipe in variation pipe diameter at flow rate 0.58 m^3/s.

From the figure C.8, it indicated that the suitable pipe diameter can select with the intersection between cost of energy loss and cost of pipe in terms of annual worth. The suitable pipe diameter is summarized as follows [22] :



Pipe Dimension

OD: Outside Diameter,

ID : Inside Diameter,

t : Thickness.

Figure C.9 The characteristic of pipe.

From the table B.3 the available data of steel pipe with total pipe length of 490 meters can summarize by the following:

- Type of pipe — Wrought Iron or Schedule 40 Steel Pipe,
- Inside Pipe Diameter — 478 mm or 0.478 m,
- Friction loss — 0.484 m at 100 m length.

Therefore, the head loss due to friction loss is as follows :

Head Loss = 0.484 m x 4.9 = 2.352 m

b) Estimate cost of piping work incase of expansion pipe diameter

To reduce the head loss for more the power capacity by expansion the inside pipe diameter of 575 mm (See table C.3) and total of pipe length is 490 m by following the previous calculation, (See appendix B, Section B.3.2). The details and estimation cost of piping work for the rehabilitation on existing Nam Pha MHP can summarize as follows:

Summary details of piping work of the project incase of expansion pipe diameter.

- Type of pipe is	Wrought Iron or Schedule 40 Steel Pipe
- Inside Pipe Diameter is	575 mm
- Friction loss is	0.192 m at 100 m length
- Total friction loss is	(0.192 x 4.90) = 0.94 m
- Pipe thickness is	6 mm
- Out side pipe diameter is	580 mm
- Unit Weight is	384 kg/9m length
- Unit cost of pipe is	1,539 US$/1pipe
- Total Cost of pipe is	84,670/55 pipes at total length 490 m
- Total cost of pipe support is	12,700 US$ at 15% of total cost of pipe
- The total cost of piping work is	97,370 US$**.**

APPENDIX D

COSTS ESTIMATION WORK SHEET

LIST OF TABLE

Table

Table D.1 Costs Estimation Worksheet.

Item	No. of Unit	Cost per Unit	Total Amount
I. Civil Work			
Intake weir			
Intake			
Headrace Canal			
Forebay/Head tank			
Powerhouse and tailrace			
Access to site			
Gate and trash rack			
Piping Work			
Penstock pipe			
Penstock Support			
Total civil work cost			
II. Electro-mechanical equipment			
Turbine and generator set			
Controller			
Transformer and switch gears			
Transmission line/Distribution line			
Total electro-mechanical equipment			
Total planning and development costs			
III. Miscellaneous (10%)			
IV. Annual costs			
Operation and maintenance			
Spare part			

Note: Applies only for micro-hydropower plant of this study [14].

The feasibility for setup Micro Turbine generator from Irrigation Valve Mea Ngut SomBoon Hydropower Plant

Mea Ngut micro-hydropower project was established in year 2007 which is an installed capacity is 100 kW by EGAT. The cost of each item is summarized in the table D.2

Table D.2 Costs Summary for Mea Ngut micro-hydropower Project.

No.	Item	Unit	Total Amount
I.	Mechanical Work		
1)	100 kW water Turbine (Propeller Type)[1]	US$	30,000
2)	Inlet valve	US$	9,000
3)	Relief valve	US$	9,000
	Sub Total	US$	**48,000**
II	Electrical Work	US$	
1)	Generator (Induction generator)	US$	25,000
2)	Turbine and generator control set	US$	15,000
3)	Main Transformer (set)	US$	10,000
4)	DCS System	US$	15,000
	Sub Total		**65,000**
III.	Civil Work		
1)	Powerhouse	US$	16,800
2)	Connecting to irrigation canal and drainage	US$	20,000
	Sub total		**36,800**
IV.	Piping Work		
1)	Water pipe and support	US$	30,300
	Sub Total		**30,300**
	Total equipment cost		180,100
V.	Miscellaneous (10%)	US$	18,010
	Grand Total		**198,110**

Note: Exchange rate is 33.04฿/1USD, Siam Commercial Bank (June, 16 2008)

[1]The turbine is designed and made from Tatoongna Hydropower plant EGAT Thailand.

TOYOTA TSUSHO CORPORATION

PRO-FORMA INVOICE

Manufacture TOSHIBA 18 May 2005 [8]

Table D.3 Costs of micro-hydropower Generating Equipments (Hydro-e-KID).

Item	Description	Q'ty	Unit Price (US$)	Amount (US$)
I. Hydro e-Kids				
	1) 100 kW Water Turbine (Type-M) - Propeller type - Runner & GV + SCS 6 / Shaft ; SUS403	1	44,990	44,990
	2) 600A inlet Valve - Automatic control, air compressor accumulating type	1	40,000	40,000
	3) 100 kW Induction Generator - 440V, 50Hz, 1000rmp, class-F Drip Proof, Self Cooling, CW	1	20,500	20,500
	4) Control Measuring & Protection Panel - Start & Stop Sequence control system & protection relays	1	17,500	17,500
	5) 600A Pressure reducing valve (Manual type)	1	13,700	13,700

Note: Cost of each items are estimated in the unit cost per 100 kW

Costs of hydropower plant equipments of

Mini/micro hydropower plant in Northern Thailand

Thesis Pradert Intub, 2003 [17]

Table D.4 The suitable price of the turbine and control system with the standard size.

Installed capacity (kW)	Turbine (US$/kW)	Control System (US$)
1-25	6,726	-
26-50	6,726	-
51-100	1010	33,631

Note : Rate Exchange 33.04 Bath/US$ SIAM COMMERCAIL BANK (June 16 2008).

Table D.5 The suitable price of the generator with the standard size.

Standard size	Installed capacity (kW)	Unit price (US$)
Small	20	3,105
Medium and Large	40	4,865

Table D.6 The suitable price of the transformer with the standard size.

Standard size	Installed capacity (kW)	Unit price (US$/kW)
Small	20	2,847
Medium and large	40	3,105

APPENDIX E

COST FORMULAR FOR QUICK COST ESTIMATE UNDER THE THE MASTER PLAN STUDY ON SMALL-HYDROPOWER IN NORTHERN LAOS

LIST OF TABLE

E.1 Costs Estimation for Feasibility Study on Small-Hydropower in Northern Laos.

The various Cost Formulas for quick cost estimate on the many identified schemes. The cost formulas are established based on the construction cost data obtained in various project in Lao PDR. Under the Master Plan Study, the preliminary cost estimate for the direct cost was made for main cost item of its key parameter show in table E.1.

Table E. 1 The main costs item with key parameters.

Main cost Items	Key Parameters	Costs Formula
Hydropower Generation Plan	Installed Capacity (kW)	
	Design Discharge (m^3/sec)	
	Head (m)	
Intake weir	Height of Weir (m), Length of Weir (m)	4,000 US$/$m^2$
Headrace Channel	Design Discharge (m^3/sec) Length of headrace (m)	Formulas including channel excavation and concrete lining.
Head Tank	Design Discharge (m^3/sec)	Formulas including channel excavation, wet masonry and concrete lining.
Penstock	Design Discharge (m^3/s), Length of Penstock (m)	Formulas including the concrete work and penstock weight.
Powerhouse	Installed Capacity (kW)	200 US$/kW
Turbine and Generator	Installed Capacity (kW)	400 US$/kW
22 kV Distribution Line	Length of Distribution line (km)	10,000 US$/kW
Transformer	No. of villages to be electrified	6,000 US$/Unit

Access Road	Length of Access Road (km)	50,000 US$/km

The cost estimate at the pre-feasibility study level is generally conducted buy applying the Unit Price Method. The direct construction cost of small hydropower project generally consists of thee components for the following major work:

1) Civil Work,
2) Electro-Mechanical Work.

Table E.2 The major work item of small hydropower plant [10].

Component	Work Items
Civil Works: i.e. (Intake Weir, Intake, Headrace Channel/Tunnel, Head Tank, Penstock, Powerhouse, tailrace ,etc	Excavation-common
	Excavation-common
	Excavation-common
	Excavation-common
	Concrete
	Cabion
	Wet Masonry
	Miscellaneous
Electro-Mechanical Works (Metal Work, Distribution Work, etc.)	Steel penstock/Pipe line
	Gate and Trash racks
	Turbine and Generator
	Distribution line
	Transformer and Switchgears
	Miscellaneous

E.2 Costs of Civil Work for Quick Costs Estimation

The costs estimates under taken by other studies/projects in Lao PDR .Several Unit price for civil work are also available at PDIH. Table below shows the major Unit Price of the Civil Works to be applied under the Master Plan Study on Small-Hydro in Northern Lao PDR.

Table E.3 Unit Price for the master plant study on Small-hydropower Plant in Northern Laos

Work Items	Indexes	
	Unit Price	Unit
Excavation-Common	1.50	US$/m^3
Excavation-Channel	2.00	US$/m^3
Excavation Rock	4.50	US$/m^3
Excavation-Tunnel	50.00	US$/m^3
Wet Masonry	70.00	US$/m^3
Cabion	70.00	US$/m^3
Concrete	220.00	US$/m^3
Gate	6,000	US4/ton
Powerhouse	40	US$/kW
Penstock	4000	US$/ton
Turbine & Generator	6000	US$

Source: [10]

APPENDIX F
CONFERENCE PAPER

SUSTAINABLE DEVELOPMENT FOR MICRO-HYDROPOWER PLANT IN LOUANG PRABANG PROVINCE OF LAO PEOPLE'S DEMOCRATIC REPUBLIC (CASE STUDY NAM MONG MICRO-HYDROPOWER PLANT)

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ABSTRACT Nam Mong Micro-Hydropower Plant (MHP) has an installed capacity of 70 kW. It is an isolated system plant which having dummy load governor function. Since year 2000, Nam Mong MHP has been generated electricity and sells to seven villages in Nam Bak District directly where the energy demand is only 60% of the energy generated. Thus, the surplus power generated in daytime is released through dummy load by conversion to heat. At the same time, the Electricite' Du Laos (EDL) grid is extended to the villages, been electrified by of Nam Mong MHP. Therefore, the energy demand tends to decrease with the increasing of consumers who satisfy the reliable electricity from EDL grid.

The purpose of the study was to show how to maintain the operation and to improve the energy generation. The synchronous system which is Semi-Auto control system was planned to set up for connecting the 22 kV Nam Mong grid to the grid of Electricite' Du Laos (EDL). Results of study based on an import tariff from PEA form Thailand of 0.0563 US$/kWh, Discount rate at 10% the electricity demand has been approximately 121,620 kWh/year or 65% of real energy generation of 185,909 kWh/year and the energy surplus of 64,086 kWh/year was used, it was found that the project was technically feasible and economically acceptable by the economic key indicators, i.e. NPV, B/C, IRR and Unit Energy Cost, was 17,901 US$, 2.40, 33%, and 0.0235 US$/kWh respectively Therefore, the synchronous system with Semi-Auto control system is necessary for the Nam Mong micro-hydropower plant.

Keywords: Micro-hydropower plant, Energy generating, connects to national grid of Laos.

1. INTRODUCTION

The government of Lao People's Democratic Republic (Lao PDR) has the political point of view that to increase the electrification rate for the whole country to 90% within year 2020. To get this aim, two strategies are applied which are (i) promotion of electrification in un-electrified province/district center and (ii) reduction the electricity import from neighboring country. Moreover, the power transmission line and distribution network have been formed and extended. While the electricity network has been expanded to raise the electrification rate, the role of small/mini and micro-hydropower plants has been decreased.

Luang Prabang is one of eight Northern Provinces of Lao PDR which located in the center part and becomes the subsidiary electricity supply center of the EDL. In this region, the electricity energy demand is rapidly increased annually. At present Luang Prabang electricity center has been electrified by the power source from Nam Ngum 1 hydropower plant and three local small/micro-hydropower plants Nam Dong (1,000kW), Nam Mong (70 kW), and Nam Pha (16 kW). Many attempts have been done to maintain these existing mini/micro-hydro power plants.

The objective of this study is to demonstrate the technical viability and economic feasibility of an improvement by installation the synchronous for connecting the grid of Nam Mong to the grid of EDL. The surplus of electricity energy was approximately 35 % of real energy generating and will be taken into account to estimate the benefit of the project. The economic key indicators such as NPV, B/C ratio and IRR will be used to evaluate the project viability for helping the decisions making for an implementation the project.

2. STUDY CONCEPT

Since year 2000, Nam Mong MHP is operated as an isolated system plant which has dummy load governor function. Therefore, the aim of this study is as a feasibility study of an installation synchronous system for connecting to the gird. The study is conducted in following stages.

2.1 Data collection

The preliminary stage is to find out the general information and technical terms of Nam Mong MHP. They are shown table 1 and 2.

Table 1 The Project location [6]

Province	Luang Prabang
District	Nam Bak
Village	Nam Mong
Distance	About 120km from Luang Prabang, 2hrs by car

Table 2 Feature of generation plant [6]

Items	Parameters
Maximum Discharge	$0.55\ m^3/s$
Effective Head	18.1m
Installed Capacity	70 kW

The generating facilities and the operation process of Nam Mong MHP which is designed as an isolated grid system are not complicated. The generation plant facilities after improvement with installing the synchronous system is shown in the figure 1.

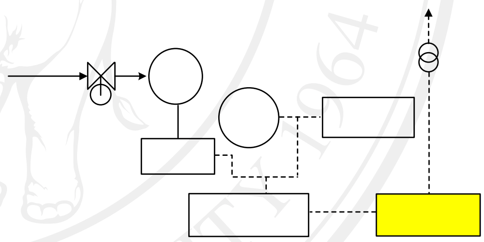

Figure 1 the generation plant facilities

Follow the operation data of Nam Mong MHP, It should be noticed that the status of electricity supply, i.e., the energy consumption tends to decrease in years 2006-2007while the increasing of consumers who satisfy the reliable electricity from EDL's grid, and plant factor seems to be very low compared to the maximum energy potential of (70 kW x 8760 hours= 613,200 kWh/year) They are figures2-3 respectively.

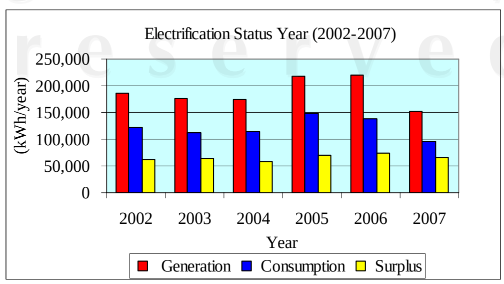

Figure 2 The electrification status [6]

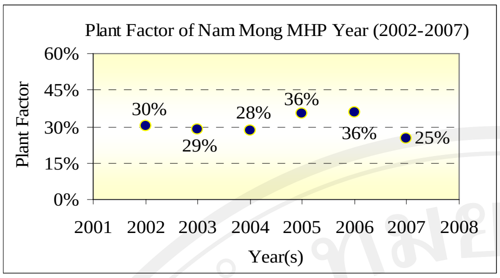

Figure 3 Plant factor of Nam Mong MHP [6]

2.2. Economic Study

Many of economic parameters are used for evaluation the project viability. The parameters for the economic study are as follows:

(a) Estimated cost

Estimated costs are an important stage in evaluating project. It will be required for selection options to support the discussion and necessary negotiation for approving and financing to the project.

For the study of an installation the synchronous system to Nam Mong MHP, it is only concentrated on costs, i.e., The costs of installation, costs of the synchronous system components and costs of improvement the electro-mechanical control system if it is necessary for connecting the to the EDL's grid. The estimated costs are based on the data form of the Analysis of Cost Benefit of Synchronization for Mae Kampong Hydro Power Plant Project 3 to Provincial Electricity Authority of Thailand (PEAT) Grid System [5], and from information received from various manufactures, which have experienced EDL. The estimated costs would be expressed in USD currency at the current price level [1]. They are summarized in the table 3.

Table 3 The summary of the estimation costs of the project [5]

No	Items	Cost (US$)
I. Equipment Costs		
1.	Synchronous system accessories	3,600
2.	Protection System	1,800
3.	Distribution line	1,000
	Sub total	6,400
II. Installation Costs		
1.	Electro-Mechanical work	1,300

Table 3 (Continued)

2.	Electrical work	1,300
	Sub total	2,600
Total Costs of Equipment and installation		9,000
III. Miscellaneous (10%)		900
	Grand total	**9,900**

(b) Economic criteria

The 70 kW Nam Mong MHP produces the average of real energy of 185,809 kWh/year. An average energy surplus is 64,806 kWh/year and it is then directly used to estimate the benefit of the project. The minor extract due to the maintenance shutdown and other activities, those were excluded in calculation.. The average import tariff of at 22 kV level from PEA that is approved by the government of Lao PDR, is the monetary concerns of project and is used for economic assessment. The discount cash flow technique is adopted, showing the factor such as Net Present Value (NPV), Benefit-Cost ratio (B/C) and Internal Rate of return (IRR).

The adopted criteria are as follows:

- Estimate the economic life is of project 20 years,
- Maintenance cost are 2.5% investment cost, applied annually [4] and are increased depended upon of the inflation rate[1]
- The electricity tariff of 0.0563 US$/kWh, referred to Import tariff rate from PEA Thailand at 22 kV [2].
- Discount rate is about 10% depending loan rate in US$ currency [1]

3. RESULT AND DISCUSSION

The results of feasibility study in case of Nam Mong MHP that the plant factor is fixed at 35% and based on the economic criteria. It is shown in table 4

Table 4 The economic analysis results

No.	Descriptions	Results	Unit
1.	Project Cost	9,900	US$
2.	Net Present Value	17,901	US$
3.	Benefit-Cost ratio	2.40	
4.	Payback Period	3.69	Year (s)
5.	Internal rate of return	33	%
6.	Unit Energy Cost	0.0235	US$/kWh

As seen in table 4, the project was

economically acceptable. The economic key indicators such as Net Present Value (NPV), Benefit-Cost ratio (B/C), Internal Rate of Return (IRR) and Payback Period were 17,901 US$, 2.40, 33 % and 3.69 years respectively.

Follow the operation data when the synchronous system would be set up to Nam Mong MHP. It could be produced more electricity energy. Therefore, the plant factor should be increased. The undoubted result of B/C ratio, and IRR was increased while the Unit Energy Cost was decreased in proportion to the plant factor, and they were shown in the figure 4 and 5.

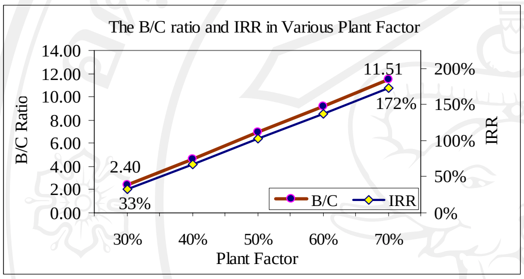

Figure 4 The B/C ratio and IRR.

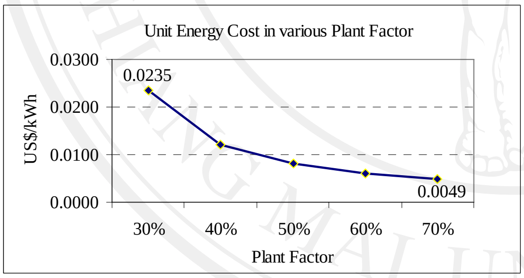

Figure 5 The Unit Energy Cost

4. CONCLUSION

The feasibility study for installing the synchronous system with a Semi-Auto Control System to Nam Mong MHP for connecting to the EDL's grid at the 22 kV level is considered. The energy surplus of 64,086 kWh/year directly relates to assess the economic analysis of the project with the total costs of the project is 9,900 US$. The result of the study shown, it is technical sound and based on the economic assumption that the electricity tariff of 0.0563 US$/kWh and discount rate 10%, it is found that the project is economically acceptable by the economic key indicators, i.e., NPV, B/C, IRR, Payback Period and Unit Energy Cost are 17,901 US$, 2.40, 33 %, 3.69 years and 0.0235 US$/kWh respectively. Therefore, the concept of an improvement by installation the synchronous system to Nam Mong MHP with 100 kW of installed capacity is extremely reasonable and contributed to sustainable development.

5. ACKNOWLEDGEMENT

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In my opinion, ASIA has become a key part of the global economy.

China, Japan and India are three of the ten largest economies. China has successfully developed itself to be a leading country, it also plays role in the international arena. Japan and India can lead in terms of technologies. Besides, ASEAN countries have constantly increased all round cooperation. Once the ASEAN's free trade area (AFTA) fully operated, ASEAN would attract more investors and it would become the world market destination and this could contribute to the leading role in the world market.

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